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OF THE

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1852

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

NOVEMBER 5, 1851.

Capt. Collinson, R.E., was elected a Fellow.

The following communications were read:—

1. *Notice of the occurrence of an* EARTHQUAKE *at* SANTIAGO *and* VALPARAISO, *on the 2nd of April*, 1851.

[Communicated from the Foreign Office, by order of Viscount Palmerston.]

2. *On the* SLATE ROCKS *of* DEVON *and* CORNWALL. By the Rev. A. SEDGWICK, F.R.S., G.S. &c.

AFTER a painful interruption of three years, I resumed my geological work during the past summer, and revisited some portions of Devonshire and Cornwall, a small part of the typical Silurian country (of Sir R. I. Murchison), a part also of the Cambrian groups of North Wales, and lastly some groups of the newer fossiliferous slates of Westmoreland and Yorkshire. I rejoice to appear once more as a fellow-labourer, and to lay the first-fruits of my summer's task before the Geological Society.

My present notice will be confined to Devonshire and Cornwall.

It is well known to all who take any part in the working of our Society, that during the past year Sir R. I. Murchison, after an examination of certain fossils sent to him from Cornwall, has introduced some new colours into the geological maps of Cornwall and South Devon*. Thus, he colours the great headlands, between the Bays of St. Austell and Falmouth, *Lower Silurian*. Again, he colours a considerable part of the coast in the neighbourhood of Looe, &c., *Upper Silurian*; and the same colour is extended to a portion of the slates of South Devon which skirt the north side of the metamorphic rocks of Bolt Head and Start Point. The first change of colour is grounded on good evidence; for in the great headlands S.W. of Austell Bay there is a development of rocks with a remarkable mineral structure, and with fossils which I should call Cambrian, and which Sir R. I. Murchison calls Lower Silurian. If I mistake not, there is, however, rather too great an extension given to the new colour in this part of the map of Cornwall. As to the Upper Silurian colour, it was put in hypothetically, or on imperfect evidence; and I believe, that both from Devonshire and from Cornwall it must be expunged as erroneous.

During my short tour in Cornwall, Professor M'Coy was my fellow-labourer. *Before* we started on our tour he had come to the conclusion, that many of the dark-coloured fossils, derived from the Cornish coast near Fowey, Polperro, and Looe, were not the remains of Fishes, but portions of Sponges. It was after a very careful microscopic examination (in which he was assisted by Mr. Carter of Cambridge) of specimens partly collected by myself in 1836, and partly procured from Mr. Peach, that Professor M'Coy had come to this conclusion; and during the past summer it has not been invalidated, but greatly confirmed, by an inspection of the Cornish specimens in the London Museum of Practical Geology, as well as those we afterwards collected during our tour, or found in the public and private collections of Cornwall. All evidence for the existence of Upper Silurian rocks in Cornwall, derived from fossil Fishes, seems to be done away, and the same remark applies to other supposed Upper Silurian fossils†.

When Sir R. I. Murchison and myself commenced our examination of Devonshire in 1836, our first and main object was to determine the true position of the culmiferous beds which were known to contain many common Carboniferous fossils. After making traverses from the north to the south shores of the county, and after using all other means in our power, we came to the conclusion that the Culm-system of North Devon was deposited in a trough superior to all the other palæozoic rocks, and that it was overlaid by no rock older than the New-red-sandstone; and hence, that this system (as there

* See Geological Map of England, published by the Soc. Diffus. Useful Knowledge. See also Trans. R. Geol. Soc. Cornwall, vol. vi. p. 317 *et seq.*

† After my return from South Wales in 1846, Professor M'Coy proved, in like manner, by microscopic examination, that certain supposed fragments of Fish-bones from the Llandeilo Flags had been erroneously determined. See also Quart. Journ. Geol. Soc. vol. vii. p. 264.

was no longer any physical evidence opposed to the palæontological) must be regarded as Carboniferous*.

At the time this conclusion was published in 1836, we had only determined the south base of the culm-trough at one point near Oakhampton. But soon afterwards the whole southern line was determined by myself with a near approximation to its present position on our geological maps of Devonshire and Cornwall.

But if the culm-trough of North Devon were of the Carboniferous period, it seems to follow, almost as matter of course, that many of the older rocks of North and South Devon must belong to the period of the Old-red-sandstone. Their position in the natural sections, in some places their mineral character, and all their fossils, so far as then known in South Devon, tended to this conclusion. Yet for reasons recorded in the former volumes of our 'Transactions,' this conclusion was not drawn by us until near the close of 1838. During the early part of the summer of 1836, we determined correctly the principal physical groups of the older Devonian rocks, and I will briefly enumerate them in this place, and give them names, not for the purpose of stating anything new or unknown, but for the purpose of more easy reference to the physical structure of Cornwall, respecting which I have never before stated my views, in any detail, to this Society.

The first and oldest of these groups may be conveniently called the *Plymouth Group*, using these words in an extended sense, so as to include all the limestones of South Devon and the red sandstones superior to the Plymouth limestone. The equivalent to this group in North Devon includes, I think, the Ilfracomb and Linton limestones as well as the red sandstones of the north coast.

The second group includes the slates expanded from Dartmouth to the metamorphic group of Start Point and Bolt Head, and is, so far as I know, without fossils: it may be called the *Dartmouth Group*; and its equivalent in North Devon is found in the slates of Mort Bay, which end with beds of purple and greenish sand-rock and coarse greywacke. It ranges nearly E. and W. across the county.

The third group is not, I think, found in South Devon; but in North Devon it is well-defined, commencing on a base-line of sandstone-beds which range nearly east and west from Baggy Point (on the western coast) to Marwood (which is a few miles north of Barnstaple), and thence towards the eastern side of the county. This group is continued, in ascending order, to the slates on the north shore of Barnstaple Bay; but its very highest beds are seen on the south shore of the bay, dipping under the base of the Culm-measures.

The equivalent of this third and highest Devonian Group is found to the south of the great culm-trough, in a group near the top of which appear the limestone-bands and fossiliferous slates of Petherwin. It may be called the *Barnstaple* or *Petherwin Group*, and I shall generally use the latter name, because it enables us more directly to connect this group with the older deposits in Cornwall.

* See Report Brit. Assoc. 1836, Transact. Sections, p. 96; and Trans. Geol. Soc. 2 Ser. vol. v. p. 682.

Bearing these three groups in mind (for they were previously made out by Sir R. I. Murchison and myself), I entered Cornwall in the autumn of 1836, and traced what I have called the Plymouth Group to Looe, Polperro, and Fowey, and thence round to St. Austell Bay; and I collected fossils from all the places above-named. Nothing which I have seen or learnt during the past summer, has changed my views respecting the age of the rocks spread along this portion of the coast of Cornwall; of course excepting the old Cambrian rocks (above alluded to) which run down to the headlands called the Dodman and Nare Head.

I did not during the past summer examine the coast from Veryan to Falmouth Bay; but I persevere in the opinion I formed in 1836, that all the slate-rocks S.W. of Gerrans Bay are nearly on the parallel of the Plymouth Group, and therefore true Devonian rocks; and to the same group I refer all the slate-rocks to the west of Falmouth Bay, between the granite and the great plateau of the Lizard. This may, however, be thought a somewhat rash conclusion, as I have not carefully examined the sections through the slate-rocks immediately north of the Lizard plateau since the year 1819.

While following the fossiliferous Plymouth group along the south-eastern coast of Cornwall in 1836, I had no assistance from any published work; and in this part of my task I preceded Sir H. De la Beche; but while terminating my tour along the north-western coast, I derived the greatest assistance from the notes and sections which he kindly communicated to me, thereby enabling me in a few days to visit the best fossil-bearing rocks, and to gain a knowledge of the country which might have cost me several months had I laboured without his help. All the rocks of this north-western coast from St. Ives Bay to a headland considerably to the north of Cligga Point, I then supposed to belong to the Middle Devonian Group (*Dartmouth slate*); and so far as I made out, were without fossils.

But, guided by Sir H. De la Beche's notes, I found a highly fossiliferous group extending from New Quay to Mawgan Porth and Padstow, and thence to Tintagel; and not merely ranging near the coast, but running far up the interior of the country, until in some instances it approached a central boss of granite, and became metamorphic. Thus, for example, in following a section a few miles south-east of Tintagel, I found the rocks passing into a highly crystalline chiastolite-slate; yet among them were some clear impressions of the well-known long-winged Spirifers of Tintagel. Beyond Tintagel, I found the same group wrapped round the northern end of the great protruding boss of granite, and thence prolonged, with a great change of strike, into the Petherwin Group above noticed.

Hence it followed, that although a line drawn through the great central bosses of granite might, in a certain sense, be called the mineral axis of Cornwall, yet it by no means represented the range of the oldest slates of the county; for the great zone of slates on the S.E. coast was apparently on the strike of the old Plymouth Group; while the fossiliferous zone on the N.W. coast, last described, was the westward prolongation of the Petherwin, or newest Devonian Group.

Had any one inquired what was the date of the slates in the central portions of the county, between one boss of granite and another, I should have replied, that many of these rocks were too much mineralized and penetrated by veins, to give any certain indication of their age; but that considered collectively, they were nearly on a parallel with the Middle Devonian or Dartmouth Group.

Such were the general results of my tour in the autumn of 1836. The slate-rocks of Cornwall and Devon, whatever might be their age, formed one connected and inseparable system; and this conclusion was in a subsequent year embodied in a single sentence, in a paper on the "Devonian System," published by Sir R. I. Murchison and myself, wherein we affirmed that all or *nearly all* the slate-rocks of Cornwall were of the Devonian age, and therefore on the parallel of the Old Red Sandstone. Why, the reader may ask, was the *saving clause* introduced into this conclusion? I must honestly state that I did not at that time anticipate the probability of finding, on the south-eastern coast of Cornwall, any older rocks than those of the Plymouth Group; but I did believe it probable that some older rocks *might* be brought to the surface near the central portion of the county, by the elevation of the great bosses of granite; and on that account the *saving clause* (just alluded to) was introduced into our Devonian Paper.

After revising the evidence during the past summer, I now think that the south-eastern promontories of Cornwall (such as the Dodman, Nare Head, and St. Anthony's Point) are exactly the spots where we ought to look for rocks older than the Plymouth Group; and that we have at present no good reason for expecting any great expansion of older rocks in the central parts of Cornwall. For this change of opinion I shall give some reasons in the sequel.

If the slate-rocks spread out along the N.W. coast of Cornwall belong (as above stated) to the Dartmouth and the Petherwin Groups, we cannot, it may be said, expect any great development, on the north side of the granitic axis, of rocks as old as, or older than the Plymouth Group. While making this remark, I wish to keep in reserve one possible exception. There is a great spread of slate-rocks between Bodmin and the mouth of the Padstow River, and the sections are complicated. The peculiarity of these sections was pointed out to me by Sir H. De la Beche in 1836, and it is I believe on his information that Sir R. I. Murchison has conjectured, that some old Silurian rocks *may* have been elevated into the sterile ridges called Pydar Downs, which rise a few miles to the south of the Padstow River, nearly on a line drawn from Bodmin to Mawgan Porth. Now it is a matter of fact that a very old Devonian group with many fossils, collected and partly described by Mr. Giles* and Mr. Peach†, exists in the neighbourhood of Liskeard. It might be called the *Lower Plymouth Group*; or perhaps, more conveniently, and to avoid ambiguity, the *Liskeard Group*. This *Liskeard Group* is prolonged to the neighbourhood of Bodmin; but in many places in that

* Trans. R. Geol. Soc. Cornwall, 1849, p. 93, and 1850, p. 155.

† *Loc. cit.* 1849, p. 103.

neighbourhood the rocks are so mineralized as to lose all distinctive characters. If the slate-rocks near Bodmin belong to a very old part of the Devonian system, it is no doubt *possible* that the coarse quartzites of Pydar Downs may be still older: but I did not visit them during the past summer, as I learnt from my friend Mr. Whitley, of Truro, that he had examined them from end to end, without discovering a single fossil; and I still believe them to be Devonian.

On the whole, therefore, after the excursions of the past summer, I retain the same opinion of the age and grouping of the slate-rocks of Cornwall that I had in the year 1836, with the very limited exception of the two headlands of the south coast, called Nare Head and the Dodman. But if such were the facts, how came it to pass that the Devonian system was not at once established by Sir R. I. Murchison and myself in the year 1836, when we determined the great culm-trough of North Devon to be Carboniferous? The reason is well known. We sent a good series of the fossils of the Petherwin and Barnstaple Groups to London. They were examined and named, and every species was called Silurian. How this mistake originated I do not now inquire, but I suspect that our package of fossils had been misplaced, or mixed with fossils of an older age. However this may be, the mistake inflicted on me the labour of a considerable part of two summers. During a portion of the summers of 1837 and 1838 (in the hopes of clearing away this difficulty, and never for a single moment suspecting any great mistake in the determination of the fossils of these groups) I traversed many parts of Devon and some parts of Cornwall again and again, seeking for faults where they were not to be found, and for anticlinal and synclinal lines where nature had never formed them; and at the end of the summer of 1838, I returned with the conviction that the first section of Devonshire, made by Sir R. I. Murchison and myself conjointly, was essentially right, and that Cornwall bore the same relation to Devon which I had supposed on my return from that county in 1836. Were then the sections and fossils to continue in a permanent contradiction to one another? If so, the *Devonian System* would never have been heard of; but on re-examining the fossils in 1838, it turned out that all the species of the Barnstaple Group had been wrongly named; and that so far from being Silurian, the only doubt respecting them was, whether they might not be called Carboniferous rather than Devonian. Thus the physical, and fossil evidence were brought into harmony: and I may add, from this example, that no good classification either of subdivisions or systems, or of subordinate formations, ever can be attempted without a previous determination of the physical groups. The study of fossils, based on ascertained physical groups, may produce, and often does produce, some modification of our lines of demarcation; but the evidence of sections must ever remain as the primary basis of geology. When a system has been well made out, and its groups of fossils determined, we may then make use of comparative groups of fossils freely, and with very small risk of mistake. But to begin with fossils, before the physical groups are determined, and through them to establish the nomenclature of a system, would

be to invert the whole logic of geology, and could produce nothing but confusion and incongruity of language.

Soon after the publication of the paper on the Devonian System by Sir R. I. Murchison and myself, Mr. Griffith re-examined some large deposits in the South of Ireland, finally separated them from the older rocks, and, on the evidence of their fossils, determined by Professor M'Coy, arranged them with the Carboniferous System, giving them the name of *Carboniferous Slates*. At the same time he stated that many of the fossils in the "carboniferous slates" were identical with the species found in the highest Devonian Groups—those of Petherwin and Barnstaple. Since that time doubts have been entertained respecting the line of demarcation between the Devonian and Carboniferous systems; nor have these doubts been invalidated, but rather confirmed, by the excellent and copious lists of fossils published and described by Prof. Phillips. I rejoiced, therefore, in having, during the past summer, the assistance of Prof. M'Coy in examining the quarries near Petherwin and the sections immediately north of Barnstaple; and I will endeavour to give some of the results of this examination in a very condensed form.

Petherwin Quarries.—Here were found two species of *Trilobites* of the genus *Portlockia*, viz. *P. latifrons*, Bronn, and *P. granulata*, Münster. The same genus occurs at Croyde Bay, N.W. of Barnstaple, and it is found in the Eifel country. Taken by itself, it would be considered Devonian; for the Carboniferous genera have hitherto been confined to *Phillipsia* and *Griffithides*, M'Coy. The genus *Clymenia*, which I first saw in 1836, is very abundant near Petherwin, especially in the old Lanlake quarry. Phillips gives seven species from this locality*. Through the kindness of Mr. Pattison we are enabled to add to this list one of Münster's species (*C. bisulcata*), and three others that are new, viz. *Clymenia Pattisoni*, *C. quadrifera*, and *C. Münsteri*, M'Coy†. We found also *Producta subaculeata*, Murch., a true carboniferous-slate fossil. Near this quarry I also found in 1836, close to the overlying black culm-slates, innumerable examples of a small Bivalve, the *Sanguinolaria elliptica*, Phillips. This species is also found in very deep denudations near Yeolm Bridge, and at Underwood Farm, several miles within the south boundary of the culm-measures. In these places, which have been described by Mr. Pattison‡, all the overlying culm-shales have been swept away; and the Petherwin Group, abounding in fossils, has been brought to the denuded surface in the form of a saddle. For many other species of the Petherwin fossils I must refer to the copious list given by Phillips§.

Baggy Point, Marwood, Barnstaple, &c.—At Baggy Point we

* See Palæozoic Fossils of Devon, Cornwall, and W. Somerset, 1841, p. 124.

† See "Description of the Palæozoic Fossils in the Cambridge Museum," 4to, by Prof. M'Coy, forming Part II. of the "Synopsis of the Classification of the British Palæozoic Rocks, by Prof. Sedgwick." The first "Fasciculus" of Part II. has appeared, the second is in the press.

‡ See Trans. R. Geol. Soc. Cornwall, vol. vii. p. 64.

§ *Op. cit.* Synopsis, p. 142 *et seq.*

found all the species of *Cucullæa*, so-called, and the specimens are there quite as abundant as at Marwood. It is the *Dolabra* of M'Coy; and several of the species are found in the "yellow sandstone" of Ireland. Mineralogically indeed, as well as zoologically, the Baggy Point sandstone agrees very closely with the Irish "yellow sandstone." Along with the *Dolabræ* was a new species of *Leptodomus*, *L. sulcatus*, M'Coy. Under the *Dolabræ* of Marwood we found several specimens of the *Aspidaria* of Römer, a true Carboniferous fossil; and it would appear from the statements of the late Mr. Williams, that Vegetable fossils are not rare in the Marwood Group.

It would be idle to detain the reader, in such an outline as this, with any account of the fine examples of an oblique slaty cleavage in Croyde Bay, of the calcareous concretions, and of the numerous fossils between Marwood and Barnstaple. Copious lists may be selected from Phillips*.

Mr. Griffith's original statement of the very near agreement of the *Carboniferous slate* of Ireland with the groups just noticed is completely confirmed by what we saw this summer; and that the "carboniferous slate" is an integral portion of the Carboniferous series of Ireland appears now to admit of no doubt.

The black shales, which underlie the culm-limestone on both sides of the great culm-trough of Devon, are of great thickness, sometimes contain (as we learnt from the collection of Mr. Pattison) the common *Posidonia* of the culm-limestone, and form an excellent and well-defined physical base to the whole culm-series. But below them there is, in the Petherwin and Barnstaple Groups, a very great physical as well as palæontological change. Physically at least, the Petherwin Group is far more nearly connected with the Devonian, than with the Carboniferous groups. On the contrary, it appears to admit of no doubt that the Petherwin and Barnstaple Groups are zoologically more nearly connected with the Carboniferous than with the Devonian groups. Prof. Phillips† states that Mr. Gilbertson had obtained a specimen of *Clymenia* from the Mountain-limestone of Ireland; but it deserves remark, that, considerably before the time alluded to, Count Münster had obtained a *Clymenia* from the Carboniferous rocks of Ireland. So far as this evidence goes, it seems to prove that the Petherwin Group ought rather to be classed with the Culmiferous series than with the Devonian. On the other hand, several of the facts stated by Count Münster seem to prove that the Clymenia-groups of the Fichtelgebirge are Devonian rather than Carboniferous. While this kind of evidence is in conflict, I would retain the good physical base-line of the culm-series, nearly as it was laid down by Sir R. I. Murchison and myself; and in doing this I have the entire concurrence of Prof. M'Coy. Were I, however, to colour geologically the maps of Devonshire and Cornwall, I should give an intermediate tint to the groups here noticed, in order to mark their true place in the series, and their very near connexion with the overlying Carboniferous groups.

So far I have been reviewing a series of facts that have often been

* *Op. cit.* † Palæozoic Fossils, p. 124.

discussed before, and have been illustrated not only by several distinct memoirs*, but by the two excellent and very elaborate volumes published by Sir H. De la Beche and Professor Phillips†; I must now shortly notice the more recent discoveries of Mr. Peach, and of some other good Cornish observers. In general we have, both in Cornwall and Devonshire, a considerable approach to symmetry in the positions of the great mineral masses. For example (not to mention three or four minor protruded granitic masses) we have in these counties five great bosses of granite; and as a general rule the immediately surrounding slate-rocks, whatever be their age, dip from the protruding granite in a symmetrical form. In the southern parts of Cornwall the mineral axis, defined by a line drawn through the several centres of the greatest bosses of granite, strikes in a direction about N.E. by E.; but in the northern part of Cornwall, and in Devonshire, the mineral axis, defined in the above manner, strikes nearly east and west. It is also true, that in both counties, when we are removed from the immediate disturbing influence of the granite, the slaty masses have a strike approximatively parallel to the two directions just indicated.

The great mass of granite that forms the moors north of St. Austell has broken through the slate-rocks not far from the point where the granitic axis of Devonshire and Cornwall has been bent, or perhaps broken. Some great disturbing forces have modified the symmetry of this part of Cornwall, affecting, I believe, the whole transverse section of the country from the headlands near Fowey to the headlands south of Padstow. However this may be, there is an unusual want of symmetry in the position of the rocks south of the St. Austell granite. In the great open mine-work of Carglaze, about two miles N.E. of St. Austell, we find a very remarkable, veined schorlaceous granite. On it repose the slate-rocks (or killas), in the usual symmetry and conformity to its surface; and near their base they show such beautiful laminations of schorl and earthy feldspar, that one formation seems to pass almost insensibly into the other. When I first saw this phænomenon in 1819, I thought, what I by no means think now, that it almost proved the truth of the Wernerian hypothesis‡. Here then we have the usual collocation of the slate-rocks.

If, however, we continue our examination of the line of junction near St. Austell, we find the killas penetrated by elvans, traversed by mineral veins, and presenting that semi-metamorphic structure so commonly seen near the granite; and some of the great mineral masses, instead of rising towards the steep granitic hills, appear to

* Especially the following:—"On the Physical Structure of Devonshire," by Prof. Sedgwick and R. I. Murchison, Trans. Geol. Soc. N. S. vol. v. p. 633. "Notes on the Age of the Limestones of South Devonshire," by W. Lonsdale, *op. cit.* vol. v. p. 721. This memoir contains an elaborate and critical enumeration of papers and works referring to the subject. "On the Geology of the South-east of Devonshire," by R. A. C. Austen, *op. cit.* vol. vi. p. 433. See also the Transactions of the Royal Geological Society of Cornwall.

† Report on the Geology of Cornwall, Devon, and West Somerset. 8vo, London, 1839; and Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset. 8vo, London, 1841.

‡ See Trans. Cambridge Phil. Soc. vol. i. p. 108.

dip towards or under them. Farther south, and along the western shore of St. Austell Bay, we find several elvan-dykes, one appearing to branch off like a granite-vein,—another containing fragments of the killas, through which it has broken its way to the surface. The whole section, as far as the Dodman, indicates the action of more than one great disturbing force. There was an elevating force protruding the St. Austell granite; and, if I interpret the phænomena correctly, there was a contemporaneous elevating force, acting from the south; and between these two forces, the beds, now spread over the surface from the St. Austell granite to the Dodman and Nare Head, were broken, contorted, and placed in their present disturbed position. With these preliminary remarks I proceed to notice the phænomena presented by the rocks which descend towards these two headlands.

A few fossils have been found on the west side of St. Austell Bay; we believe them to be Devonian; and we do not think it possible to interpolate any rocks of an older epoch in this part of the section; and we apply the same remark to a large group of rocks, which range through the interior of the country from the N.W. side of St. Austell Bay to Veryan. Starting with this assumption, we began our examination of the coast between Gerrans Bay and Gorran Haven, under the guidance of our friend Mr. Whitley, of Truro. Our work commenced in Gerrans Bay; and near the road leading from the sea-shore to the village of Veryan we found one of those numerous raised beaches which are met with along the Cornish coast.

The prevailing rock along the north-eastern part of the bay was a bluish-grey slate (killas), much penetrated, here and there, by quartz-veins, and puckered and contorted in its subordinate parts, but on the whole dipping steadily to a point about 10° east of magnetic S. at an angle of 40°. To the north of this group, on the road towards Veryan, the beds are still more puckered, more highly inclined, and contain concretionary masses, and thin bands of limestone. But neither among these beds, nor at Veryan, did we find a single fossil. Their prevailing strike is 15° or 20° east of true N., and the dip as before is constantly to the S.E. side.

Returning to the section along the eastern shore of the bay the blue killas is followed, to all appearance, in ascending order by a coarser arenaceous greywacké, sometimes very ferruginous and decomposing; and here and there it is associated with a flaky conglomerate, exactly like many of the conglomerates commonly found in North Wales and Cumberland among the oldest slates. Over the preceding rocks comes a remarkable, white quartzite, 30 or 40 feet thick, dipping nearly S.E., and the quartzite is overlaid in its turn by earthy and ferruginous slates, by conglomerates almost passing into trap-shale (or *schaalstein*), and by very ferruginous beds of trap. Of rocks like these there are several alternations, to the extreme headland, which prove that the trappean and aqueous rocks were contemporaneous; and they preserve the same south-eastern dip to the end of the section. The rocks here described, when considered mineralogically, have, perhaps, an older look than the ordinary

Cornish killas, but this fact is considered of no great importance. Considered with reference to the section, they seem to be the newest rocks of the coast. The section is *to all appearance* an ascending section; and we discovered no trace in the cliffs of any fault or break of continuity; still less did we find any apparent axis of elevation to explain the appearance of a group older than the common Devonian rocks. But the very rocks above-described strike through the country towards the N.E. and come down to the coast a few miles N. of the Dodman, near Gorran Haven; and in course of their range several Cambrian fossils have been discovered in them by Mr. Peach. The true position of these beds is, therefore, important; and in confirmation of what has been just stated, I subjoin a section, by my friend Mr. Whitley, through the same series of rocks to a point on the coast a little east of Nare Head. (See fig. 1, p. 12.)

In this section, the most northern portion seems exactly to represent the beds at the head of Gerrans Bay. The beds from the schistose sandstone and quartzite to the end of the section are but a repetition of the beds to the south of the great quartzite-band, which are seen on the eastern coast of the bay above-described: nor have we here any fault or break of continuity; and the overlying rocks, near the sea-cliff, seem to be the newest strata in Mr. Whitley's section.

Leaving the sections near Nare Head (and taking no further note of many interesting phænomena, such as the protrusion of a boss of serpentine on the east side of the headland), we passed along the coast of Veryan Bay, and found at Porth Caerhays a coarse brown greywacké, alternating with thick beds and masses of conglomerate. Some of the conglomerates were coarse and contained pebbles and concretions of limestone; others were of finer texture, and, in some parts of the cliff, passed into coarse slate, and in others, into trap-shale. Altogether the group nearly resembled some rocks we had left behind; the whole cliff was highly ferruginous, and the dip was nearly in the same direction as before.

From Caerhays we passed across the headland to Gorran Haven, which is to the south of the remarkable quartzite-band above noticed. The quartzite-band reaches a high part of the cliff called the Great Carn, and a little further north is a cliff called the Great Peraver. The dip of the beds is steadily towards a point about south-east by south, and at a high angle; and the same, or nearly the same dip is continued towards the Dodman. Hence we might be led to conclude (as indeed I had done myself during a former visit in 1836) that the rocks between Great Peraver and the Dodman were the newest in that part of the Cornish coast. (See the south end of Section, fig. 2, p. 12.)

On the south side of Gorran Haven are alternations of finely laminated slates with a ferruginous gritstone; and the beds are frequently disturbed and puckered, but have an average dip about magnetic south, at an angle of 60° or 65°. On the north side are seen some beds of coarse greywacké, of fine glossy dark slates, penetrated by innumerable quartz-veins, also of some singular concretionary masses, and conglomerates. Fossils have been found in the more calcareous por-

Fig. 1.—*Section of the Slate-rocks from Gwendra to the Blowth, near Nare Head.* Mr. Whitley.

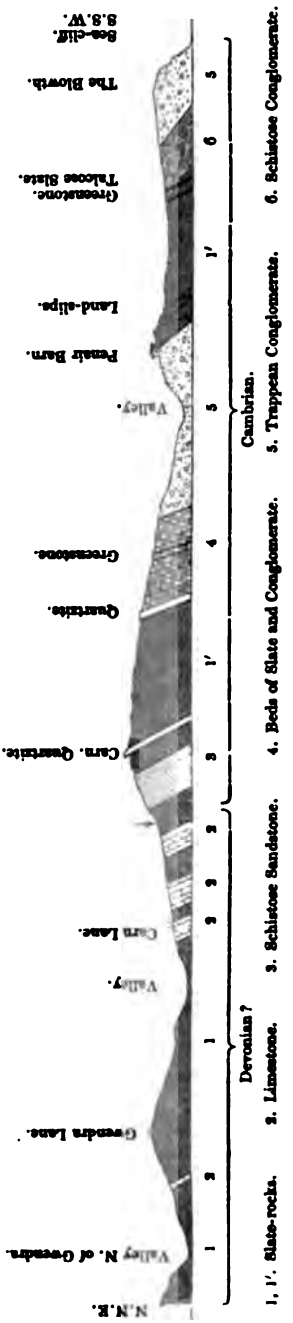
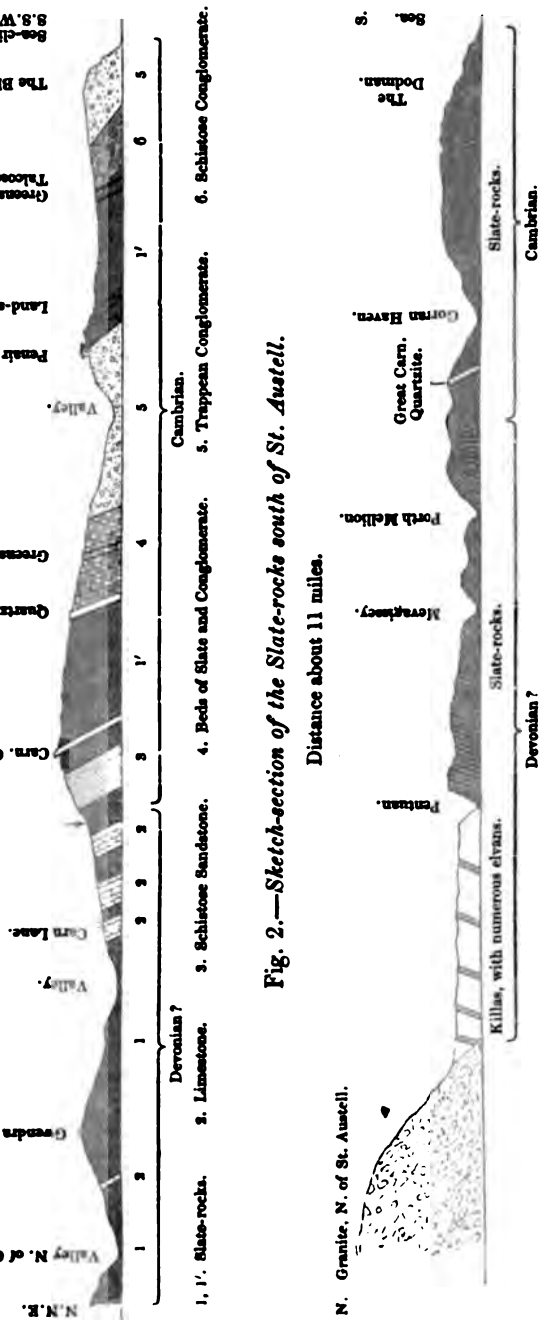


Fig. 2.—*Sketch-section of the Slate-rocks south of St. Austell.*



tions of these rocks. The quartzite of the Carn retains its usual structure, and contains fossils. Farther north, from under the rocks of the Carn, rises a series of brownish ferruginous grits and coarse slates, like those under the quartzite of Gerrans Bay; and these grits at Great Peraver also contain many fossils.

A single day's excursion round the headlands above-noticed, commencing at Truro and ending at St. Austell, and made during very unpropitious weather, could not lead to the discovery of many fossils. But in the Museums of Penzance and Truro we had seen a good collection, made with great labour, chiefly by Mr. Peach, from the rocks I have just noticed; and I subjoin the following list, from the species now deposited in those museums, with a reference to the places where the several species were found.

From Great Peraver north of Gorran Haven:—

Orthis elegantula, *Dalm.*; rare.
—— parva, *Pander*; very abundant.
—— calligramma? *Dalm.*
—— turgida, *M'Coy*; very abundant.
—— flabellulum, *Sow.*; very abundant.
Calymene brevicapitata, *Portlock.*
—— parvifrons? *Salter.*
Homalonotus bisulcatus, *Salter.*

From the quartzite of the Great Carn:—

Orthis testudinaria, *Dalm.*; abundant.
—— retrorsistria, *M'Coy*; abundant; plentiful also in a part of the Bala group.

Near Porth Caerhays:—

Orthis grandis? *Sowerby*; a Bala species.
Cycloceras ——, a species like one in the Wrae Limestone, Upper Tweed.

All the above species (with the locality of each specimen carefully recorded) are placed in the museum at Penzance, and were carefully examined by Prof. M'Coy, kindly assisted by Mr. Crouch, the Honorary Secretary of the Cornish Geological Society; and, with a like kind assistance from Dr. Barham and Mr. Whitley, we found several duplicate specimens of the same species, and from the same localities, in the museum at Truro. Specific names were not affixed to many of the specimens, and for the previous list I rest entirely on the authority of Prof. M'Coy.

From the above list (I believe in near accordance with one lately given by Sir R. I. Murchison*), it is obvious that a large group of beds with fossils of the Cambrian (Lower Silurian) age exists along the line of coast above described. But from the previous descriptions, and from Mr. Whitley's section, fig. 1, the group appears to overlie the calcareous slates of Veryan, which we suppose to be Devonian. In like manner, if we examine the coast-section from the head of St. Austell Bay to the Dodman, we find the fossiliferous group between Peraver and Gorran Haven in what appears to be a high part of the

* Trans. R. Geol. Soc. Cornwall, *loc. cit.* p. 321.

series. A detailed section of the whole coast, from the head of St. Austell Bay to the Dodman, might perhaps throw some new light on the questions I am here discussing; and such a section I hope to receive from my friend Mr. Whitley. Meanwhile the following notes, with the accompanying outline-sketch of the succession of phænomena seen to the south of St. Austell*, are the best evidence I have to offer.

Near St. Austell, and thence down to Pentuan, the prevailing dip is towards the north, and the highly mineralized beds do not appear to hang from, but generally towards, the granite (see fig. 2). From Pentuan to Mevagissey there is the same prevailing northern dip. In Mevagissey Harbour the slate-rocks are nearly perpendicular, with breaks and shifts of strike, indicating faults; but on the south side of the harbour the dip is steadily Magnetic North, at a great angle (about 80°). This northern dip (interrupted by two undulations) prevails towards Porth Mellion. On the north side of the Porth the beds dip Magnetic North, at a very high angle. At the Haven Head the rocks are perpendicular, and seem to belong to the pommel of a broken saddle. On the south side of Porth Mellion the dip is nearly Magnetic South, and at a high angle. From this part of the coast there is a prevailing southern dip, and generally at a high angle, as far as the extreme point of the Dodman. South of Porth Mellion there are, however, two changes of dip, and the anticlinal and synclinal lines are marked by the presence of fractures and innumerable quartz-veins. Both of these changes come in between the Porth and the farthest low headland that is seen from it towards the south-east.

All along the coast, from Pentuan as far as this low headland, the rocks have nothing peculiar in their structure to indicate an age differing from that of the best-known Devonian rocks of Cornwall; but at this headland the beds become coarse and sandy, like the beds which underlie the quartzite in Gerrans Bay; and beds of like kind, striking at a high angle, and with a steady dip towards the south, are carried under the quartzite of the Great Carn. And thus we are conducted to the fossiliferous group between Peraver and Gorran Haven.

Beyond Gorran Haven the southern dip continues; but the lines at the south end of the accompanying sketch, fig. 2, are put in from memory, as I have not visited the coast south of Gorran Haven since 1836.

Such are the facts (so far as I can pretend to have observed them), presented by a very perplexing part of the Cornish coast. There is, we believe, no trace whatsoever of any great anticlinal axis, bringing up a series of older rocks among the newer Devonian slates of the country; and we cannot regard it as a reasonable hypothesis, to suppose that such a group of fossils, as has been given above, can belong to a true *Devonian System*, in the sense in which these words were first used by Sir R. I. Murchison and myself.

To explain the difficulty three hypotheses suggest themselves for consideration.

* See also Tr. Geol. Soc. N. S. vol. v. p. 666, and Geol. Rep. Cornwall, &c., pl. 2. f. 3 (S. end of Section).

1. It might be supposed probable that the rocks on both sides of the granitic axis, between the Land's End and St. Stephen's Moor, near St. Austell, belonged to an older system than the corresponding rocks in the other parts of the county: and I have already noticed the difficulty presented by the sections along a line drawn from St. Austell Bay to the north coast. I do not, however, believe that this hypothesis is at all probable; but it ought to be tested by a severe examination of all the sections between Truro and Falmouth, and in all the southern parts of the county, where the condition of the rocks offers any chance of discovering fossils. It had been stated that Mr. Peach found *Graptolites* at Black Head, a few miles south of St. Austell. On examining the specimens of the supposed *Graptolites*, in the museums of Penzance and Truro, Prof. M'Coy found that they had been wrongly named. They belong to a new species of *Cladochonus*, which is a Coral of a Carboniferous genus*: and at Pridmouth, near Menabilly, on the opposite side of St. Austell Bay, the same species of *Cladochonus* is found amongst many undoubted Devonian species which we collected on the spot.

2. The second and more probable hypothesis is, that a great *fault*, with an *upcast* towards the south, has brought the fossiliferous group above described into its present relative position among the Cornish rocks. We looked in vain for the traces of such a fault in Gerrans Bay. In a valley about half a mile north of Great Carn (fig. 2) we at first supposed that we had discovered the line of fault; but this opinion was not based on any adequate evidence; and the settlement of this point must be left to future observers.

3. Lastly, among beds so highly inclined and contorted as those in the cliffs south of St. Austell, it is neither impossible nor improbable that the southern parts of the section may be presented to us in an inverted position. Extensive cases of inverted sections are now familiar to all geologists, and at present I am inclined to adopt this hypothesis (not, however, without much hesitation) as perhaps more probable than the former.

The above-noticed irregularity of position between the slaty masses and the granites is also seen on the east side of St. Austell Bay. From the head of the bay, towards Lostwithiel, the beds skirting the granite are mineralized and penetrated by innumerable veins; and (on the evidence obtained during a former year) I believe that one or two very great faults range up the country towards Lostwithiel. If we quit the mineralized district, and descend towards Gribben Head, we find a prevailing dip towards the north: but at a point of the coast about a mile south-west of Fowey, there is an anticlinal axis striking across the headland; so that the dip of the beds at Gribben Head is nearly south-east, and at a high angle. Numerous fossils have been found on the coast between Fowey and Gribben Head. From one single quarry we collected about a dozen species, all of which were Devonian without any admixture of Silurian or Cambrian types. Among the Devonian species of this part of the coast may be mentioned the *Portlockia latifrons*, Bronn, sp.

* Pal. Foss. Cambr. Mus. part 2, fasc. 1, p. 84.

The same prevailing northerly dip is seen on both sides of the Fowey River, and is continued along the coast to the headland on the south-west side of the Looe River. A highly fossiliferous series of beds, striking nearly east and west, occupies an irregular trough, the south side of which is represented by the cliffs between Fowey and Looe. We think that the confusion of the Cornish sections which we remarked near St. Austell is extended to Looe, where there is a great north and south break, beyond which the position of the slate-rocks is less disturbed; so that a section made from the granites near St. Cleer, through Liskeard, and thence down to the coast on the east side of the Looe River, seems to present an ascending series, as regular as the ascending series we meet with in Devonshire, between Dartmoor and the south coast of that county near Plymouth Sound.

In the 'Transactions of the Geological Society of Cornwall' are some interesting notices of the fossils found near this part of the coast*. Through the kindness of Mr. Box and Mr. Hicks of Looe, and Mr. Giles of Liskeard, a very fine series of specimens was submitted to Prof. M'Coy, and he hesitated not to pronounce them all Devonian. There was not one characteristic Upper Silurian species among them. We also procured from Mr. Lochrin (one of the Coast-guard, who is a good naturalist and an intrepid collector, treading in the steps of Mr. Peach) several good specimens from the so-called fish-beds which range from Fowey, through Lantivet Bay and Polperro, to Looe. The supposed Fishes† are Sponges of the genus *Steganodictyum*, M'Coy, which have been figured and described, and will appear in the next 'Cambridge Fasciculus.' One or two other species, which are new, will also appear in that forthcoming work. *Bellerophon bisulcatus* (erroneously marked as a Silurian species in some of the collections) abounds in this part of the series. It is a true Devonian fossil‡. In a sketch like the present it is impossible for me to dwell on the mineral structure of the several groups; but I may just allude to some very singular beds of green and reddish slates, alternating with hard quartzose beds, which appear on the coast near Looe. They are overlaid, in the trough above-indicated, by the softer Devonian slates, which in some places are calcareous, and abound, here and there, with fossils.

The new roads, cut through the Devonian slates north of Looe, give many instructive sections, which were not visible in 1836, when I followed the general strike of the beds from the neighbourhood of Plymouth to this part of the coast. In the cliff at East Looe the dip is about 30° East of true South, at an angle of 40°. The beds in the cliff are composed of hard quartzose bands, alternating with calcareous slates, in which we may often see earthy and cellular lines, that mark the presence of numerous fossils. Following the course of the river to the north of Looe we found a large, half-concretionary mass of limestone, which reminded us of the similar masses (provincially called *junks*) which are so commonly found among the

* See vol. vi. pp. 147, 220, 276, &c.

† See Trans. Geol. Soc. Cornwall, vol. vi. pp. 29, 79, and 319, and vol. vii. p. 17 *et seq.*, p. 57, &c. and pl. 1 and 2.

‡ See Römer; Verst. Hartz-Gebirg. tab. 9. fig. 1.

slates of Devonshire. Again, in a quarry by the road-side at Common Wood, a little further north, fossils are extremely abundant. Perhaps no large portion of these Devonian slates is entirely devoid of fossils; but they abound most on certain lines along which are found streaks or masses of limestone; which, I may remark, seldom burns into white lime, and appears in several cases to be magnesian. Many of these *junks* of limestone have been laid down by Sir H. De la Beche, and many more may hereafter be discovered. Our friend Mr. Box informed us that he had found masses of limestones, similar to those above noticed, at the following places between the Looe River and the Hamoaze, viz. Shuttleback, Common Wood, Treloy, Tremain, and St. Germains.

All the fossils from this neighbourhood in the collection of Mr. Hicks are the counterpart of the series from Plymouth; and nearly the same remark applies to the collection of Mr. Giles at Liskeard. A few species which are new or have been imperfectly described will be noticed, as before stated, by Prof. M'Coy in the next "Fasciculus of the Cambridge Palæozoic Fossils."

That the calcareous slates immediately north of Looe are a part of the Plymouth Group, and nearly on the strike of the Plymouth limestone, cannot admit of doubt. The beds near Liskeard are considerably lower in the series of deposits; and it was not without hesitation that I designated them by the distinctive name of *Liskeard Group* (see above, p. 5). They are certainly neither Silurian nor Cambrian, and may be regarded as a lower subdivision of the great Plymouth Group.

I wish the Society to bear in mind that some conclusions arrived at in this paper are hypothetical, and that the opinions I have stated repecting the age and distribution of the groups in the south-western parts of Cornwall are chiefly based on observations made in the summer of 1836, or during previous years. To the south-west of St. Austell Bay, hardly any Devonian fossils have yet been discovered. But in Devonshire the middle or *Dartmouth Group* is almost devoid of fossils; and if (as I think is true) this group be prolonged into the south-western extremity of Cornwall, the fact will at once account for the almost entire absence of fossils; not to mention the highly altered character of the slates in the great mining districts of Western Cornwall. Again, even in the *Plymouth Group* the quantity of calcareous matter is less developed in Cornwall than it is in Devonshire; and this fact explains the less abundance, and less perfect preservation, of the fossils in the range of this group towards the south-west.

By way of conclusion we may, I think, rationalize and explain the actual collocation of the great mineral masses in Devonshire and Cornwall, without being accused of indulging in an unreasonable spirit of hypothesis.

1. What was the condition, before the period of the Old Red Sandstone, of the physical region now occupied by the sea, both on the north and south sides of Devonshire and Cornwall, it would perhaps be idle to conjecture; but we have a positive proof that some old rocks did exist along what is now a part of the S.E. coast of Cornwall: and

perhaps the altered slates near Lizard Head and the metamorphic slates at Bolt Head might be regarded as indications of ancient strata near the site of those promontories. Again, the rocks of North Devon are highly mechanical in structure, and were evidently formed by the degradation of some older strata. The enormous breaks and disruptions, that took place in many parts of our Island before the deposits of the Old Red Sandstone began, may easily explain the absence of any large continuous deposits of Cambrian or Silurian rocks, either on the north or south side of Devonshire and Cornwall.

2. Assuming the truth of the previous statements of this paper, we may believe that a great physical group (the Plymouth Group) was deposited in a region which is now occupied by the most northern coasts of North Devon; and also along the region which is now occupied by the south-eastern coasts of Cornwall and by a part of South Devon.

3. Over this came the Dartmouth Group, ranging under the sea where now are spread out the slates of this group both in North and South Devon. But this Dartmouth Group was also largely developed on the north side of the Plymouth Group, ranging through a space which is now occupied by the central and north-western parts of Cornwall; and the same group was probably spread to the north of the Plymouth Group through a country afterwards broken through, and partly covered up by the Dartmoor granite.

4. Over the two preceding were deposited the two contemporaneous Groups of Petherwin and Barnstaple.

5. Within the period of the three preceding groups, there seem to have been extensive tracts of elevated land, covered with ancient Carboniferous Plants; otherwise, how are we to account for the great quantity of vegetable matter which, both from the north and the south, was drifted into the great culm-trough of North Devon? Of this at least we are certain, that the great culmiferous series was deposited in regular order on the three preceding groups.

6. Afterwards came the period during which the great granitic axis was elevated. When the elevatory movements began, and how long they were continued, it would not be possible to determine; but they ended before the period of the New Red Sandstone; for before that period, the granitic axis, and the other great mineral masses had assumed their present relative position. But this granitic axis was not elevated along the strike of any one of the above groups; but, commencing at the western end of Cornwall, it rose through slate-rocks, which seem to belong to the older Devonian groups, and was apparently continued, in association with the same groups, as far as the great boss of veined granite north of St. Austell, round which, as stated above, there is much confusion in the position of the stratified masses. But the great granitic mass between St. Cleer and Camelford rose between the Plymouth and Petherwin Groups, so that the Dartmouth Group almost disappears from the section. Lastly, the Dartmoor granite rose up and partially removed both the Dartmouth slates and the Petherwin Group; so that its north end abuts against, and tilts up, the base of the culm-trough, mineralizing the great culm-

limestone; while the south end of the same Dartmoor granite mineralizes and tilts up the base of the Plymouth Group.

7. Contemporaneous with the elevation of the mineral axis above described, was a mineral axis, ranging nearly east and west, and elevating the older groups of North Devon. We do not now see this mineral axis; but that it existed and produced its effects, at the time indicated, cannot, I think, admit of doubt; and it explains the high inclination, the southern dip, and the contortions of the great Plymouth Group on the coast-line of North Devon.

8. Lastly we have indications of an elevatory axis, probably contemporaneous with the two axes already noticed, ranging along the south coasts of Devonshire and Cornwall. For example, the metamorphic groups of Bolt Head and Start Point, which occupy the south end of Devonshire, are elevated at a high angle and dip towards the north. Whether these metamorphic rocks belong to a very ancient group, or are merely an altered form of the Dartmouth Group, is a question of no moment to my present purpose; but the position, as well as the structure, of these rocks favours my hypothesis of a third mineral axis. The same may be said of the igneous rocks, forming the great plateau of the Lizard district. Considered in the mass, they appear to overlie a series of slate-rocks, probably about the age of the Plymouth Group. But at their southern extremity, they bring up a group of slate-rocks of metamorphic structure and of uncertain age. This evidence is no doubt obscure, but the existence of the metamorphic slates, with the other phænomena of the district, combined with the appearance of metamorphic slates at the south end of Devonshire, are facts which favour the hypothesis of a third mineral axis.

If these views be even approximately true, they help us to account for the singular contortions of the great culm-trough of North Devon. For it must, on this hypothesis, have been exposed (perhaps for a long period of time) to continued and conflicting movements of elevation; and its beds may at the same time have been doubled up and compressed by enormous lateral forces, originating from two antagonistic lines of elevation.

Finally, a third mineral axis acting from the south helps us to explain some of the phænomena above noticed; and makes it probable that rocks older than those of any Devonian group, *may* have been brought to the surface along the line of the south-eastern coast of Cornwall; and, that such rocks do partially exist in the headlands south of St. Austell, we have a proof in the facts stated in the previous parts of the paper.

A further notice of the phænomena observed, during the past summer, in the Silurian country, in North Wales, and among the Yorkshire group of slates near Ingleton, and in Upper Ribblesdale, is reserved for a future communication.

November 19, 1851.

Stirling Benson, Esq., and Dr. John Percy were elected Fellows.

The following communication was read:—

On the Granitic Blocks *of the* South Highlands *of* Scotland. By W. Hopkins, Esq., M.A., F.R.S., President Geol. Soc. Lond., and President Cambridge Phil. Soc.

On a visit to the Highlands of Scotland in the summer of 1849, my attention was directed by my friend Mr. Smith, of Jordan Hill, to the blocks of granite which are scattered along the banks of the Clyde. Proceeding thence to Oban, I found on the shores about that place, and on the neighbouring shores of Loch Etive (see Map), similar blocks, but larger and more numerous. These were easily traceable to their source, the mass of granite immediately on the north and north-west of Ben Cruachan, and extending across the upper branch of Loch Etive. In like manner I observed numerous blocks about the head of Loch Awe, on the south-east of Ben Cruachan (see Map); and these also were easily traced to the above-mentioned mass of granite up the valley of Glenray, which runs in a north-easterly direction from the head of Loch Awe on the eastern side of Ben Cruachan. Proceeding afterwards to Loch Lomond, I found granite blocks scattered along its western shore; and I observed them in great numbers also round the head of Loch Long and of Loch Fyne. The source of these blocks presented a great apparent difficulty. The granite of Ben Cruachan was well known *, but no granitic mass, so far as I could ascertain, had been recognized by geologists, or indicated on any geological map, as standing in the same relation to the last-mentioned blocks, as that which the granite of Ben Cruachan bears to the blocks of Loch Etive and Loch Awe. In fact Ben Cruachan was the nearest known source to which the blocks of Loch Lomond, Loch Long, and Loch Fyne could be referred, if we except the red granite near Inverary; and the character of that granite is entirely distinct from that of the grey and whitish granite of which the blocks are composed. At the same time the nature of the country intervening between these localities and Ben Cruachan is such as presented the greatest difficulty in any explanation of the dispersion of these blocks which should refer their origin to that mountain. It was with the view of solving this difficulty that I devoted several weeks of the summer of 1850 to a more detailed investigation of the subject.

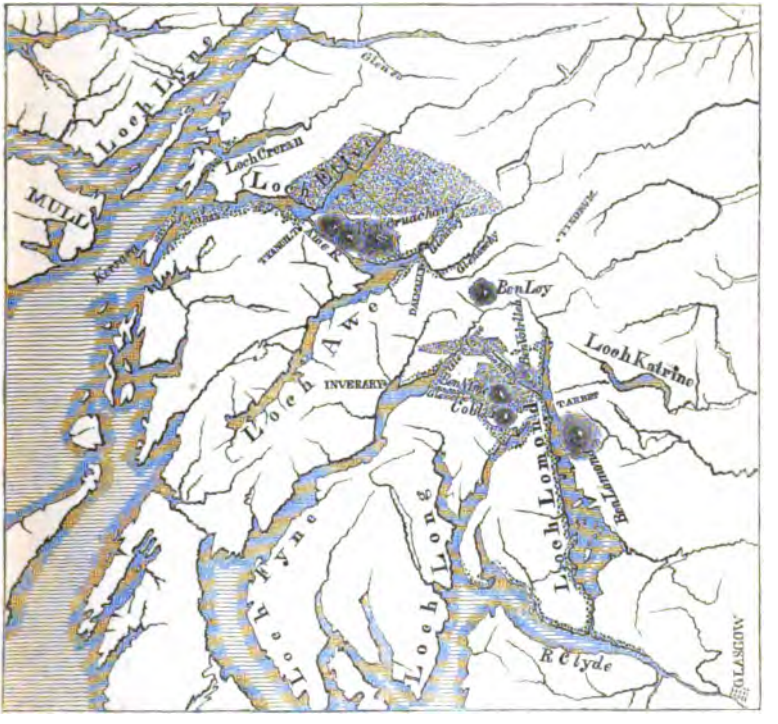
1. *Distribution of Blocks about Loch Lomond, Loch Long, and Loch Fyne.* (See Map.)

I commenced the investigation at the head of Loch Long, accompanied by Mr. Montgomery of Ayr. Of the blocks in that locality the greater part consist either of a dark-grey granite; or of

* See Macculloch's "Observations on the Mountain Cruachan," Trans. Geol. Soc. vol. iv. p. 117.

a very light-coloured granite, containing comparatively large crystals of felspar. These characters I found so distinctly marked as to indicate the great probability of these two classes of blocks being derived from different sources. They appeared to have come down the valley which forms the prolongation of that in which Loch Long

Map of a part of the South Highlands, showing the granitic nuclei of Ben Cruachan and Ben Nime, and the dispersion of the Erratic Blocks from these Centres respectively.


Loch Etive
Loch Awe
Loch Long
Loch Lomond
Loch Katrine
Ben Ledi
Ben Lomond
Ben Lawers
Ben Nevis
Ben Cruachan
Ben Lui
Ben Lomond
Ben Lawers
Ben Ledi
Ben Venue
Ben Lomond
Ben Lomond
Ben Lomond

they were also much less rounded, indicating our approach to the source from whence they came. This source was soon reached. It is a large mass of granite presenting precisely the same characters as the dark blocks which have proceeded from it. Their principal origin was thus clearly determined.

Immediately on the W. of the upper parts of Loch Long and of the lower part of the valley above-mentioned, is the mountain well known as the Cobler, and directly to the N. of it, the lofty summit of Ben Nime, which in height rivals Ben Lomond itself. If a spectator stand at the upper extremity of the valley and look to the north, Ben Nime will be situated on his left, and immediately in front he will see Ben Voirlich, also a lofty mountain, the base of which extends to the western shore of Loch Lomond. Between him and this latter mountain he will observe a valley descending rapidly eastward to Loch Lomond, which he will overlook stretched out on his right. This valley in ascending divides into two branches. The principal one runs in a north-westerly direction between Ben Nime and Ben Voirlich, defining the extent of the latter mountain from the lowest point of the valley on the shore of Loch Lomond to its upper extremity at which the small lake, Loch Sloy, is situated, at a great elevation above the larger lakes. The other branch of the valley is much shorter, and takes a more westerly direction into the bosom of the mountains immediately associated with Ben Nime. A considerable stream runs from Loch Sloy, and is increased at the junction of the two branches of the valley by water descending along the shorter valley. The rapidity of the fall must frequently render this stream a perfect torrent from Loch Sloy down to Loch Lomond.

Mr. Montgomery followed the valley on the left towards Ben Nime and found a large mass of granite *in situ*, similar to the dark-grey granite already mentioned. In pursuing the course of the larger branch to Loch Sloy, I remarked the absence of the blocks of dark grey granite, while the presence of others, although few in number, of lighter colour and containing large crystals of felspar, indicated this valley to have been the course along which the blocks of this character had proceeded from their source down to the head of Loch Long. Time, however, did not allow me to reach their source in this direction. I could only ascertain that it lay to the N. of Loch Sloy; a conclusion, which, as we shall see, was subsequently verified.

With the present configuration of the surface, whatever might be the agency of transport, the blocks coming from Loch Sloy would have the greatest tendency to descend directly eastward to Loch Lomond, as would also the blocks of grey granite descending the other valley, mentioned above as penetrating into the mountains about Ben Nime. With a little alteration, however, in the present surface, it is sufficiently obvious that a portion of these blocks would descend southward to Loch Long. These are manifestly courses which have been traversed by the blocks which now line the shores of these lakes. They are more numerous about the head of Loch Long than towards its southern part; and they also exist in considerable numbers on the western shore of Loch Lomond, from its northern limit for many

miles southward, and probably to its southern extremity, for there can be little doubt of this having been one of the courses by which the blocks of the Clyde have reached their present locality. The other obvious course is that afforded by Loch Long.

Besides the valleys above-described, there is one, two or three miles long, which runs directly from the head of Loch Long to the village of Tarbet on Loch Lomond. Numerous blocks are found along this valley, through which similar blocks have manifestly been transported from one loch to the other, probably from Loch Long to Loch Lomond, since that direction of transport appears more consistent than the opposite one with the general direction of dispersion in that quarter. There is also another valley, running directly north, from the northern extremity of Loch Lomond to Tyndrum, which might have afforded an access for blocks to that end of the lake; but on examining this valley for some distance, I was unable to find in it a single block of granite.

There is also another course along which blocks of grey granite have found their way to the upper part of Loch Long. The valley of Glencroe, along which runs the road from Tarbet to Inverary, lies immediately to the south of the Cobler, a mountain mentioned above. In proceeding westward along this valley from the lake, we observe blocks of grey granite, but neither large nor numerous until we approach a small, but rapid stream descending into Glencroe from the central group of mountains about Ben Nime, where a large mass of grey granite, as already described, is found *in situ*. The gully, down which the stream descends, is filled with blocks of grey granite, many of these being of considerable magnitude. The smaller ones only appear to have been carried forward along the valley of Glencroe. Proceeding westward along the road from this point the blocks entirely disappear, until we descend towards the head of Loch Fyne. Round the head of the loch they are very numerous, but instead of being of a dark-grey colour, they belong to the whiter kind of granite with large crystals of felspar. They are very numerous along Glen Fyne, which extends directly northward from the head of the loch, and have manifestly proceeded from a great mass of granite about four or five miles north of the loch. This granite extends across Glen Fyne to the west, and on the east it extends to the north of Loch Sloy, forming the source from whence the blocks of whiter granite, which have descended from that lake to Loch Lomond, have undoubtedly been derived.

The greater portion of the blocks on the shores of Loch Fyne have evidently come down Glen Fyne, but a portion, although probably a small one, has descended the valley along the lower part of which the road before-mentioned passes from Loch Long to Inverary. This valley runs up nearly in the direction of Loch Sloy, and penetrates, I have no doubt, into the mass of granite just mentioned. Its lower termination is at Ardkinglas, one or two miles from the head of the loch.

In this part of the Highlands there is an important group of

mountains tolerably well defined by Loch Lomond on the east, Glencroe on the south, Glen Fyne on the west, and on the north by the valley which runs eastward from the head of Loch Awe by Dalmally towards Tyndrum (see Map). The area, thus bounded, includes the Cobler on the south, Ben Voirlich on the east, Ben Loy on the north, and Ben Nime which is more centrally situated. The mass of granite I have described forms the central nucleus of this group, and it is probably to its protrusion that the formation of these mountains is in a great measure due. Its existence entirely removes all difficulty as to the origin of the blocks on the shores of Loch Fyne, Loch Long, and Loch Lomond, and on the banks of the Clyde. I have entered into minuter details than I should otherwise have thought necessary, on account of the great inaccuracy with which the physical features of this tract are generally represented on maps, and the want of any distinct recognition by former geologists of the existence of this granitic nucleus.

2. *Distribution of Blocks around Ben Cruachan.* (See Map.)

To the N.W. of the group of mountains above described is another group, of which Ben Cruachan is the highest point; and which possesses also its own central granitic nucleus. It is bounded on the east by the valley of Glenorchy, on the north by Glencoe, on the south by the upper part of Loch Awe, the Pass of Awe, and the western portion of Loch Etive; on the west it extends nearly to the sea-coast of Appin. The granitic nucleus is situated somewhat to the south of the centre of the group. It forms both banks of the whole of that part of Loch Etive which runs N.E. from Tyanuilt, and appears to form the base of the northern part of Ben Cruachan. It is penetrated also on the S.E. by the valley of Glenray, of which the southern extremity is at the head of Loch Awe; and also on the western side by the valley in which Loch Creran is situated. Numerous blocks have been transported down all these valleys. The greatest number is found on the shores of Loch Etive, as might be expected, in consequence of that loch penetrating so far into the granitic mass. From the mouth of the loch they extend along the coast to Oban and for several miles south of that place. Many have been driven on the northern point of the small island of Kerrara, just opposite Oban. They are found also on the highest point of the island, and are scattered over the hills which intervene between Oban and Loch Etive, at heights, in some cases, of several hundred feet. Very few appear to have passed from the mouth of Loch Etive in the northern direction. In like manner, blocks, but smaller and less numerous, are scattered on the shores of Loch Creran. A continued series of these blocks also exists along Glenray down to the head of Loch Awe, about which they occur in numbers, extending from thence also eastward along the valley a little beyond Dalmally, to a distance of four or five miles. They extend in the opposite direction along the shore of the loch to the entrance of the Pass of Awe, but I could

not discover any on the eastern shore within a distance of six or eight miles of the head of the loch. My examination did not extend further to the south.

3. *On the general Configuration and relative Depression of the District at the period of the Drift.*

The two granitic centres of Ben Nime and Ben Cruachan are undoubtedly those from which the granitic blocks in general in the southern portion of the Highlands have been derived. The particular courses which these blocks have followed bear no constant relation to the points of the compass. On the contrary, we find them radiating from separate centres, each line of dispersion being determined by a configuration of the surface of the country very similar to that now existing. The reason why there are no lines of dispersion towards the north in the above cases is found in the absence of any valley descending in that direction from the granitic centres. This leads us, and I think necessarily, to the conclusion that the general configuration of the district was nearly the same at the time of the dispersion of the blocks as at the present time; a conclusion, however, which does not by any means invalidate the suppositions that the position of the surface of the land may have undergone great changes with reference to the sea-level, and that the valleys may have been materially modified by denudation, during the period of submergence. There is, in fact, indubitable evidence in different parts of Scotland of the superficial configuration of the rocks older than the Old Red Sandstone having been determined previous to the breaking up of that formation; for the Old Red Conglomerates occupy entirely or partially valleys which must have existed previously to their dispersion. Some of these valleys also afford most striking instances of subsequent modifications produced by denudation. The valley, now occupied by the sea, between the island of Kerrara and the main-land near Oban, is an instance of this kind. It was obviously filled up by the Old Red Conglomerate to the depth of perhaps several hundred feet; but the greater part of this mass has been swept away by denuding agencies, which have only left a narrow fringe round the coasts as evidences of its former more extended existence. Similar modifications may have taken place in many of the valleys of the Highlands, although equally conclusive proofs may be wanting.

It has been frequently supposed that the directions, in which the general transport in this region has taken place, indicated the operation of some general cause acting from north to south, or from north-east to south-west. The facts, however, above stated prove, I think, beyond all doubt, that the conditions, which have regulated the directions of dispersion from the two granitic centres described, have been strictly local.

I am not acquainted with any phænomena within the proper boundaries of the southern Highlands, which prove the depression of this district during any portion of the glacial period to have been

equal to that of Snowdon. I think it very probable, however, that the manner in which the blocks are distributed along the sides of most of the valleys in which they abound, may be justly regarded as indicative of a position of the surface of the ocean much higher than at present, with reference to the surface of the land. On the south side of Loch Etive from Tyanuilt to the sea, and on the hills about Oban, the blocks range to the height of 300 or 400 feet, and possibly higher, according to a rough estimate by the eye. The elevation at which they are found also on the island of Kerrara is much the same. Again, on the eastern side of Loch Fyne I have observed them at apparently about the same altitude, and also on the eastern side of the Cobler, above the shores of Loch Long. Whether we suppose the blocks at these heights to have been deposited there by floating ice or transported by water, after having been brought down in part from their original sources by glaciers, it would appear probable, that the surface of the sea stood at a relative elevation somewhat exceeding that of the upper limit of the blocks, at least during the time of the transport of those which are now placed near to that limit.

That the depression of the southern Highlands has been, however, much greater at some period than that here contemplated, is rendered extremely probable by evidence afforded by the adjoining districts. The Till in these districts is not unfrequently found, I believe, at the height of 500 or 600 feet, and in some cases at the height of 1000 or 1200 feet or upwards, above the present sea-level. These facts, assuming the Till to have been of marine origin, prove the great depression to which the lower lands of Scotland must have been subjected; and I know of no reason for supposing the Highlands not to have been subjected to a similar depression.

4. *On the Modes of Transport of the Blocks.*

The three modes of transport,—by glaciers, by floating ice, and by currents of water, are all, I conceive, now pretty generally recognized by geologists as possible modes in which the transport of blocks may have been actually effected. The difficulty consists in distinguishing the effects produced by these agencies respectively. In attempting to distinguish the action of glaciers, one inquiry is, the heights of the sources to which the blocks can be traced; for, if it should appear sufficiently probable that those heights are greater than the relative elevation which the sea attained during the period of dispersion, we must attribute the first removal of the blocks from their original sites to the action of glaciers. On the north-western side of Ben Cruachan the granitic mass forms the bed of the upper portion of Loch Etive from Tyanuilt for many miles, and rises to the summit of the mountains on either side, so that there is no determinate elevation from which the blocks of that locality must necessarily have proceeded. The blocks of Loch Fyne also present an exactly similar case. In other cases the blocks must have descended from at least a certain height. The grey blocks on the shores of Loch Lomond, which have had their origin in Ben Nime, must have descended from points

many hundred feet above the present sea-level, as must likewise the blocks which have proceeded from that mountain to the south into Glencroe. Again, the blocks of white granite, which have passed down from Loch Sloy to Loch Lomond, must have descended from a still greater height. I have no means of ascertaining these heights, except by a rude estimate; but I should think they may amount to 1500 or 2000 feet. The blocks from Ben Cruachan also, in the valley of Glenray, must have descended from an elevation of several hundred feet.

From what I have stated in the previous section, it would not appear that we have any certain evidence that the depression of the land below its present level, during the drift period, ever amounted to 2000 or even 1500 feet, either in this or the surrounding districts. Still it must have approached the latter amount; nor is there any evidence of its not having been considerably greater. In Wales, too, there appears to be distinct evidence of its having exceeded 2000 feet. We can derive, therefore, from these considerations no positive proof of the former action of glaciers. If, however, we regard the distribution of the blocks along the sides of some of the principal valleys in which they exist as indicative of the relative height of the sea at the time of their transport, we obtain a presumptive proof that the blocks were brought down to that level by glaciers. To this may be added the direct indications of the former existence of glaciers. They are not, however, either very numerous or very striking in this region, although several instances of polished and striated rocks have been described by Mr. Maclaren and other observers. They are chiefly at comparatively low levels, and may perhaps, in some cases, be rather attributable to *half-floating* ice driven forward by currents, or other causes, than to glaciers properly so called.

There are indications of glaciers, however, at much higher levels. I have already mentioned the valley which descends from Loch Sloy along the western flank of Ben Voirlich. It afterwards turns suddenly eastward, at the foot of the same mountain, down to Loch Lomond. Immediately to the south of the point where the valley thus changes its direction, the general surface of the rocks is much more rounded than elsewhere, assuming the aspect which might be given to it by the passage of a large glacier over it. The locality would be favourable for the formation of such a glacier, which would be fed by one descending down the valley from Loch Sloy, and another from the valley running up into the recesses of Ben Nime, besides minor affluents. It would then descend partly down to Loch Lomond, and partly down to Loch Long, along the valley already described as that by which the blocks have reached the head of the latter loch. I could find, however, no striæ, nor, in fact, did I observe any surfaces apparently calculated to preserve them. The only other direct indication of glaciers which I remarked in this locality consisted in a block, which was not granitic, reposing on a surface of granite. It probably weighed twenty or thirty tons, and was split vertically in the manner in which large blocks deposited by glaciers are frequently divided. I may also mention, that in the valley of Glenray, and not

far from the head of Loch Awe, I observed aggregations of large angular blocks and other detritus, having the true character of moraines.

I am disposed, as I have already intimated, to refer most of the polished and striated surfaces, now found at elevations little above the surface of the sea, to floating or rather *half-floating* ice. It is, at all events, much easier to conceive and account for the existence of ice in this form in many of these localities, than to explain the existence of glaciers extending many miles along nearly horizontal valleys now occupied by the numerous lochs of the district*. It does not follow, however, that although a large quantity of ice may have existed in this form, it should have been the principal agency in conveying the granitic blocks to considerable distances; nor do I think that observation sanctions the opinion of such having been the case in this region. I have been told that there are blocks of considerable magnitude on the banks of the Clyde, but I have never seen any that might not assuredly have been transported there by comparatively moderate currents of water. As we recede from the immediate sources of the blocks which are found along the shores of Loch Lomond, Loch Long, and Loch Fyne, the blocks decrease rapidly in magnitude, and scarcely ever present that rough and angular appearance which many of them have close to their original sites. In this part of the district, the blocks which are at all remote from their sources appear to me for the most part, although there may be particular exceptions, to have the character of blocks transported by water through the latter part of their course, whatever may have been the mode of transport nearer to the points from which they originally came. On the south side of Loch Etive, the decrease in the size of the blocks as they recede from Ben Cruachan does not appear to me so rapid as in the cases above mentioned, although they decrease and rapidly disappear along the coast to the south of Oban. The best test, however, by which we might determine whether considerable masses of floating ice had or had not been the effective agency in transporting blocks down Loch Etive, would be afforded by an examination of the opposite coasts of Mull; for, if such has been the case, it would appear extremely improbable that a considerable number of blocks should not have been conveyed to that island. I regret that bad weather and other causes prevented my making this examination.

Some geologists seem to have manifested of late an indisposition to admit the agency of currents of water in the transport of erratic blocks. The effectiveness, however, of this agency in the transport of blocks larger than the great majority of those with which we are

* It is in this manner that I conceive the polished and striated rocks to have been produced in the neighbourhood of Edinburgh and other places in the eastern parts of Scotland. If the ice floated with perfect freedom, it would be very difficult to account for the determinate directions of the striæ; and no rational explanation can be given of glaciers moving, in the proper sense of the term, over so flat a region. *Half-floating* ice, impelled perhaps by incidental currents, appears to me to afford the most rational explanation of the phænomena. The notion is very similar to that frequently advocated by Sir Roderick Murchison.

here concerned, is demonstrable, if we admit the existence of such currents as must necessarily have resulted in this district from elevatory movements, not much greater in magnitude than those which have taken place during the historic period. I may also remark, that in discussing this subject, we are too apt to direct our attention exclusively to the phænomena of what is emphatically termed the Drift-period. It should be recollected that some of the older geological periods furnish us also with records of similar phænomena. The conglomerate of the Old Red Sandstone in the western Highlands presents an enormous aggregation of boulders of considerable magnitude. In the neighbourhood of Oban, it is seen in immediate juxtaposition with the erratic blocks of granite. The blocks of the older period have evidently been subjected to very great attrition, and have thus doubtlessly been much reduced below their original size. Many of them, probably, were as large as the neighbouring blocks of granite. Mr. J. C. Moore, also, in his paper "On the Fossiliferous Beds of Wigtonshire*," has described some very remarkable beds of conglomerates containing, among smaller boulders, rounded blocks of 4 or 5 feet in diameter, and regularly interstratified with other beds. Mr. Griffith has also described Silurian conglomerates in Connamara containing blocks of great magnitude. It would seem extremely difficult to assign the transport of these blocks to any other agency than that of water.

There are also phænomena connected with the denudation of this district which ought to be discussed in conjunction with the transport of its erratic boulders. Most geologists will probably allow the validity of the reasons above assigned for the opinion that this region was submerged several hundred feet beneath the surface of the sea during a portion of the glacial period, and that it was principally during that period that the dispersion of the granitic blocks took place. Now, if this period of submergence was a tranquil period, what is become of the sedimentary beds which must necessarily have been formed in a quiet sea? Instead of such beds, of which there is scarcely a trace, we have one part of the region swept almost perfectly clean of all recent sedimentary matter, and another part occupied by the tumultuary deposit of the Till. I cannot doubt but that a considerable portion of this deposit was derived from the valleys of the Highlands, and was transported from thence by currents which were produced by repeated elevatory movements of that part of the district, and which not only swept away any new sedimentary deposits, but also still more deeply excavated the pre-existing valleys. I can conceive no other agency of sufficient power to sweep out accumulated matter from some of the Highland valleys (as that for instance of Loch Awe), which are deep and extensive, but want all open communication with the Lowlands or the ocean. These same currents, partially at least, I consider to have been instrumental in the final dispersion of the blocks previously brought down from the mountains,

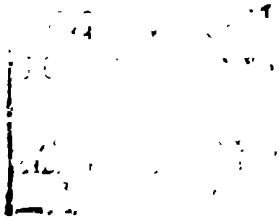
* Quart. Journ. Geol. Soc. vol. iv. p. 10, 1849. See also Sir R. Murchison's account of Silurian Conglomerates in Ayrshire, *op. cit.* vol. vii. p. 149 *et seq.*, 1851.

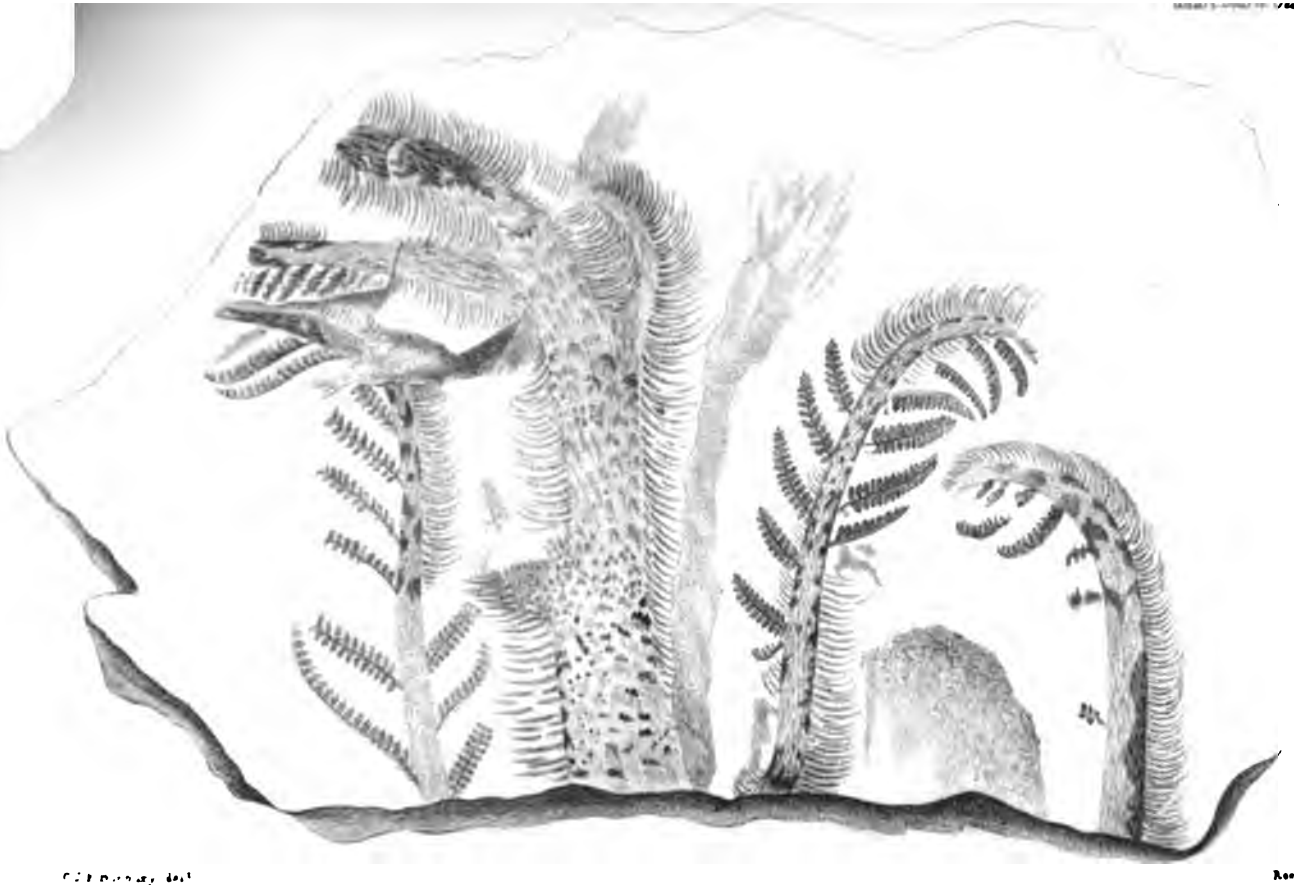
as already intimated, by glaciers, and carried probably, in part, still further by floating ice, before they became subjected to the influences of the currents in question.

It may be thought that the non-existence of granitic boulders within the mass of the Till is a proof that the transport of the boulders and the Till did not take place at the same time and by the same agency. This argument appears to me conclusive against the opinion that any considerable portion of the Till may have been transported by ice, because there is no reason why a glacier or floating ice should not deposit the smaller detritus together with the blocks with which it may be simultaneously laden. But such would not be the case with currents of water. A current rushing down a submarine valley in consequence of an elevatory movement of the central mountains would proceed with diminished velocity as it reached the lower and wider parts of the valley, and especially when it should have escaped into the more open region beyond. It would thus first lose its power of moving the larger, and then of the smaller blocks; while it would still retain the power of transporting the finer detritus to greater distances. A transient current of this kind, accompanying a wave of elevation, could only transport a block of a given magnitude a certain distance, as I have elsewhere shown *. Another similar wave at a future time might carry it a certain distance further, and so on for successive waves; but, if the valleys down which they proceeded were sufficiently long, a continued succession of these waves might be necessary to transport the blocks to that more open region in which these waves would deposit successive layers of finer matter, and on reaching that more open space they would be left on the finer matter previously deposited there. According to this process, wherever the blocks and finer sediment should be found together, the finer sediment would invariably form the lowest stratum. In the southern Highlands, the limits within which there is any considerable number of blocks scarcely extend to the boundaries of the Till, and blocks are scarcely ever, I believe, found imbedded in it. Mr. Griffith has informed me that he believes the limestone boulders of Ireland to repose in many instances on the finer detrital matter, and M. d'Archiac cites several observers who testify that the same arrangement obtains very generally in the north of Europe†. It will probably be found to be a very general character of most masses of drift. The explanation here given of it does not at all interfere with the theories of the transport of the larger and more angular blocks by ice, for it is intended to apply more especially to those smaller and more rounded blocks which are usually found at considerable distances from the original sources whence they have been derived.

* Transactions of the Phil. Soc. of Cambridge, vol. viii. Part 2.

† See also Murchison's 'Russia.'





Reeve & Nichols lith.

Fossil Fern from Cape Breton

December 3, 1851.

T. A. Tagg, Esq., the Rev. H. M. De la Condamine, and W. B. Beaumont, Esq. were elected Fellows.

The following communications were read:—

1. *Description of a peculiar* Fossil Fern *from the* Sydney Coal Field, Cape Breton. By C. J. F. Bunbury, Esq., For. Sec. G.S.

[Pl. I.]

The fossil plant of which I propose to give an account was communicated to me some time ago by Richard Brown, Esq., from the coal-mines of Sydney, Cape Breton. I have shown it to several of my most learned friends, both botanists and geologists, who have all pronounced it to be entirely different from anything they had previously seen; nor have I been able to find any fossil with similar characters represented in any published work. The appearance of the specimen is indeed so peculiar and extraordinary, that its discoverer, who is well known to have an intimate acquaintance with the fossils of the Sydney coal-field, conceived it to present an actual union of the structures and characters of two distinct families. I have thought, therefore, that a careful description and figure of so singular a fossil might not be unacceptable to the Geological Society. Although I fear I must confess myself unable to give a very satisfactory explanation of the anomalies which it presents, still it seems desirable that the peculiarities of a specimen, at present unique, should be put upon record; and this notice, by exciting attention and discussion, may perhaps lead to a complete elucidation of the subject.

The slab of shale now before us exhibits four distinct portions of stem, which, from their relative position and proportion, may reasonably be supposed to have belonged to one plant. The largest, and that which appears to be the main stem, is about 4 inches long and half an inch broad, retaining pretty nearly this breadth for about half its length, and then tapering very gradually to the upper end. In direction it is wavy, curving first slightly to one side, and then more decidedly to the other, with so gentle and easy a curve as seems to show that this flexure was natural, and not the effect of pressure or violence. It shows no tendency to a dichotomous division, but bears three small and short lateral branches, which seem to be incompletely developed. The situation of these branches is irregularly alternate. The other stems which appear in the specimen are much more slender, and although their connexion with the main stem is lost, may be conjectured to be branches which sprung from it lower down. They likewise are curved, with an easy and evidently natural flexure, and two of them exhibit very plainly the circinate or involute curvature characteristic of Ferns. The surface of the main stem is pitted all over rather slightly and irregularly; the pits seeming to indicate the insertions of scales or hairs, or some such appendages; there are no definite areolæ nor leaf-scars. In the smaller stems, or branches, on the other hand, the surface presents an appearance

not unlike that of the young branches of *Lepidodendron elegans*, being marked with wavy and often intersecting striæ which form imperfect areoles; but, on closer examination, we find that these areoles are not symmetrical or well-defined, nor do they bear any distinct scars of insertion.

I now proceed to describe what is most remarkable in this fossil,—the leaves or appendages which it bears. On all the stems, and particularly on the largest, we observe great abundance of what appear to be acicular leaves, certainly much resembling those of some species of *Lepidodendron*. These are very closely crowded, very narrow, sharp-pointed, and with few exceptions, strongly incurved; for the most part indeed they are at first inclined *downward*, or towards the base of the stem, and then strongly curved in the opposite direction. Some of them show rather indistinct appearances of a central rib or ridge. The largest stem is thickly clothed throughout its length, and its lateral branches most densely, with these apparent leaves; they are now seen, indeed, only on the right and left sides, or margins of the stem, as it lies imbedded in the stone, but I conceive that they did exist likewise on the side which is now laid bare, and which is marked with the pits already mentioned. One of the smaller stems is clothed with them along the whole length of one side; on the remaining two they appear partially, occupying only certain portions, and being scarcely discoverable on others. But, besides these acicular leaves, which much resemble those of a *Lycopodium*, the smaller stems bear what are indisputably the leaves or fronds of a small *Fern*, apparently in an early and imperfectly developed state. These spring alternately from the two sides of the stem, but not uniformly, for they are wanting where the stems are most thickly clothed with the acicular leaves; some of these latter, however, are visible between the insertions of the fronds. The largest frond is about an inch long. They are of an oblong outline, narrow in proportion to their length, and much resemble the pinnæ of some of the more delicate species of *Pecopteris*, of the section *Unitæ*, such as *P. plumosa* and *P. dentata*. The back of the rhachis, where it is exposed to view, appears to be clothed with minute, narrow, pointed scales or appendages, resembling in miniature the supposed "acicular leaves" on the stem.

Such are the appearances presented by this singular fossil. That both the kinds of leaves, or leaf-like appendages, which I have described, really belong to the stems, and that the appearances are not due to any casual juxtaposition, will, I think, be quite evident to every one who examines the specimen. Mr. Richard Brown, the discoverer of the fossil, supposed it to be a peculiar species of *Lepidodendron*, bearing *two different* kinds of foliage,—namely, the leaves proper to that genus, and the fronds of a true Fern; and thus in fact combining in one plant the characters of the two families. Now, it is certainly true that the two orders* of Club-mosses and Ferns,

* I assume what I think has been sufficiently proved by M. Brongniart, that the *Lepidodendra* belonged to the family of *Lycopodiaceæ*, or were at any rate most closely related to them.

although in general widely different in their outward appearance, are very closely allied in all essential points of structure, so that all botanists have agreed in placing them next to one another, and some of the most eminent have even united them under one head. Sir W. Hooker, for instance, in two or three of his admirable works on Ferns, has actually comprehended the Club-mosses as a subordinate group. Hence it would not be utterly inconceivable, that, in a former state of the world, there should have existed plants combining some of the peculiarities of the two orders, and uniting them more closely than is done by any existing form. I am inclined to think, however, that this hypothesis is not applicable to the specimen now before us.

On a close examination of the stem, we shall fail, I think, to discover the proper characters of a *Lepidodendron*. There is no appearance of that regular dichotomous division which has been justly insisted on by M. Brongniart as an important characteristic of *Lepidodendron*; on the contrary, the only stem in this specimen which is branched, has branches irregularly alternate, and very inferior in size to the main axis. Again, the stems here have a wavy and winding character, an appearance of softness and flexibility, which I have not seen in any genuine *Lepidodendron*. In *L. elegans* and *L. gracile*, the most branched kinds with which I am acquainted, even the youngest and slenderest branches are almost always straight, and have a certain rigidity of character which is wanting here. Again, although the younger parts of the stem, in the specimen before us, exhibit superficial markings a good deal like those of the young branches of a *Lepidodendron*, yet the areoles are irregular and ill-defined, and without distinct leaf-scars. On the main stem all appearance of regular and definite areoles has vanished, and the surface is merely indented or pitted, in a manner very similar to what we observe in undoubted fossil Fern-stalks (*stipites*). On the other hand, it is well known how definite and regular are the areolar markings of true *Lepidodendra*, even on stems of great size and age*.

For these reasons, I can hardly believe that any part of the specimen in question belongs to the genus *Lepidodendron*. I may mention, too, that when I showed it to the greatest of modern botanists, he pronounced the plant to be truly a Fern, and nothing else.

The conjecture I have to offer—for I can call it no more than a conjecture—is that this curious fossil may possibly be a Fern with a creeping stem or rhizome, such as are so commonly seen in moist tropical climates, creeping like ivy over mossy rocks and old trunks of trees. *Polypodium incanum*, *P. percussum*, *P. vaccinifolium*, and *P. lycopodioides* are well-known examples of this mode of growth, and are often to be seen in botanical collections. The creeping stem of such Ferns has often a striking resemblance at first sight to a *Lycopodium*, as indeed is indicated by the name of one of the plants above-mentioned. At the same time it is by no means regularly dichotomous, but has an irregular ramification, often very similar to

* *L. selaginoides* (of the "Foss. Flora") is an apparent exception, but I strongly suspect that it is not a true *Lepidodendron*.

that of the fossil from Cape Breton. I have already noticed that the older parts of the stem, in this fossil, bear superficial markings similar to what are often seen on the fossil stalks or stipites of Ferns. And as these marks are admitted, in the one case, to be due to the removal of chaffy scales, or other such appendages of the epidermis, so I think we may suppose them to be of similar origin in the other case. I am not of opinion, however, that the stems in the specimen before us can be properly the stipites of Ferns; for their ramification, and especially the insertion of the fronds, is too irregular. On the other hand, the position of these fronds and their insertion on the stems appear to me consistent with the supposition that the whole belonged to a creeping Fern.

It remains to explain what, on this hypothesis, could be the nature of those appendages which so much resemble the leaves of a *Lepidodendron*. The only explanation I can suggest is, that they may possibly have been scales (*paleæ*), of the same nature as those which are so commonly found to clothe the creeping stems of Ferns. I must own, that among the recent Ferns with a stem of this character, I do not know any with scales similar to these in form or texture. But in *Lomaria Magellanica*, a Fern indeed very unlike our fossil in other respects, the rhizome and base of the stipes are clothed with long, narrow, pointed scales, of a peculiarly rigid character, and bearing, as I think, no small resemblance to the apparent leaves of the fossil in question. What strengthens my suspicion that these leaf-like bodies may be mere scales, is the presence of apparently similar, though much more minute, appendages on the *rhachis* of one of the fronds.

The only figure I have met with that bears any resemblance to this fossil, is that of *Selaginites Erdmanni*, in the sixth part of Germar's fine work on the fossils of Wettin. The plant there figured, although much larger than ours, has a certain degree of resemblance to it in ramification, and in the marking of its surface (particularly fig. A. pl. 26). The Wettin fossil, however, does not present the *biform* aspect which is so extraordinary in ours. Notwithstanding the opinion of so eminent a naturalist as M. Germar, I cannot help feeling great doubts whether his *Selaginites* really belongs to *Lycopodiaceæ*. Its ramification appears to me too irregular, its general form too thick and clumsy for that order of plants, and the supposed leaves with which its surface is covered, appear (in the plate) more like scales than true leaves.

To return to our Cape Breton fossil. If my explanation of its structure be correct (of which I feel by no means confident), it will indeed be less wonderful than was at first supposed, but will yet be an uncommonly interesting specimen; for instances of the fronds of fossil Ferns still attached to the stem are exceedingly rare. In formations of a later age than the Coal-measures (the Grès bigarré and the Wealden), a very few specimens have been found of Ferns* with the fronds still in their natural position, springing in a tuft from a small knotty rhizome; but I am not aware that anything similar has

* See the works of Schimper and Mougeot, and of Dunker.

been observed in the Coal-formation. The rarity, indeed, of recognizable stems of Ferns in this formation, when compared with the profusion of their leaves, is quite remarkable, and might incline one to suspect that these plants were not fossilized on the spot where they grew. It is rare to find, in the Ferns of the Coal-measures, even the stipes or leaf-stalk completely preserved down to its base: the only specimen of this kind that I have seen is a beautiful *Sphenopteris* (I believe *S. elegans*) from the Edinburgh coal-field, in the collection of Mr. Hugh Miller. On the other hand, the state of preservation of the fronds themselves seems to show that they cannot have been transported from any great distance, and I am well aware that there are strong geological objections to any hypothesis of drifting, especially when we consider the vast extent of some coal-fields. It is possible that a diligent examination of the immense carboniferous deposits of the United States and New Brunswick may hereafter throw some light on various obscure questions, both in Geology and Palæo-botany.

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2. *On the* Lower Palæozoic Rocks *at the* Base *of the* Carboniferous Chain *between* Ravenstonedale *and* Ribblesdale. By the Rev. A. Sedgwick, F.R.S., G.S. &c.

A glance of the eye over the geological map of England shows us, in the upper part of the valley of the Eden, a very remarkable re-entering angle in the base-line of the Carboniferous Limestone. Taking our point of departure from the foot of Stainmoor, we trace the Pennine Chain (which at Cross Fell reaches the height of nearly 3000 feet) in a direction about N.E. by N.; and the Yorkshire prolongation of the same carboniferous chain in a direction about S.S.W.; while another carboniferous chain, branching off from the former near Kirkby Stephen, may be traced in a semicircular sweep round the northern flanks of the great Cumbrian cluster of mountains. The re-entering angle in the base-line of the Pennine chain is partly accounted for by the intersection of two enormous breaks or faults—the *Pennine fault* and the *Craven fault**; and the whole country, from Brough and Kirkby Stephen to the foot of Stainmoor, is filled with broken masses of the Pennine chain, which have been rent off by the two lines of fracture, and thrown down, in great confusion, into the lower parts of the valley.

The Craven fault has been described in considerable detail by Professor Phillips† and myself‡. The Pennine fault, ranging near the

* See Phillips's Illustr. Geol. Yorksh. Part 2. pl. 24. fig. 14, and Geological Map, pl. 25.

† Trans. Geol. Soc. 2nd Ser. vol. iii. pp. 5–15; and Geol. Yorkshire, pp. 107, 120, &c.

‡ Trans. Geol. Soc. 2nd Ser. vol. iv. p. 60 *et seq.*, and 69 *et seq.* I gave this great break among the lower strata of the carboniferous chain the name of the

base of the Pennine chain, has not yet been carefully described*; and although, during former years, I have followed it through a considerable portion of its length, it is not my object to enter on any general description of it in this place. I may, however, remark, that some fragments of the carboniferous series on the western side of the fault are full 2000 feet below what we might call their natural position in the great Pennine chain. Can we then say, that the Pennine fault ever produces a downcast of 2000 feet on its western side? In a certain geological sense we might make the assertion correctly; for on the opposite sides of the fault there is an actual change of the geological horizon amounting to more than 2000 feet. But in the stricter sense in which the word *fault* is used by miners and practical men, there is never (so far as I have seen the Pennine fault) anything like an upcast or a downcast of 2000 feet.

In the normal condition of a fault we have a nearly vertical fracture; and, if we can examine the beds immediately on the opposite sides of the fracture, we can determine correctly the quantity of upcast or downcast produced by the fault. Such are the faults described in our coal-fields and other mining districts. But in the grander dislocations (such as the Pennine and Craven faults) the lines of fracture are seldom of a simple nature; and the beds, on the opposite sides of the lines of break, have seldom the same dip and inclination: and hence it follows, that at a comparatively short distance from the lines of dislocation there may be an enormous change in the geological horizon, mainly produced by a change of dip; although, at the same time, the upcast or downcast along the actual line of break amounts to a quantity that is comparatively insignificant†.

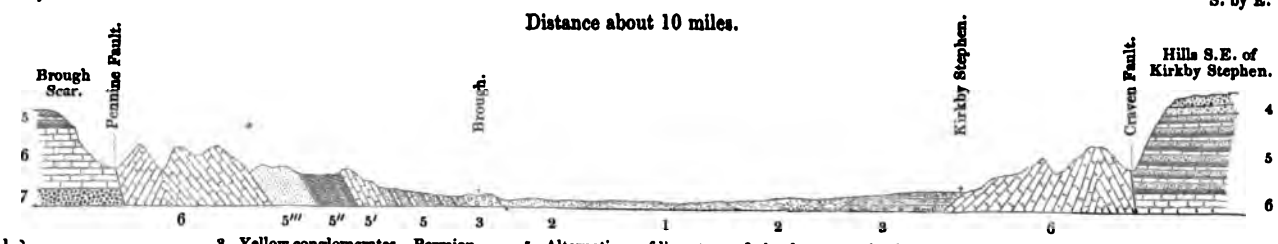
I am here stating what is little more than a truism; yet it has sometimes been lost sight of, if not in the speculations, at least in the language of geologists. To explain my meaning I will quote two instances. Between Brough and the foot of Stainmoor, the dislocations produced by the Pennine fault are so complicated that I know not how to represent them; but in the hills immediately above Brough, the relations of the strata are, I believe, correctly represented by the accompanying section (fig. 1), which crosses the line of the Pennine fault. Close to Brough, and at a low level, are some beds of the carboniferous series, which are, geologically, far above the great Scar Limestone; but their representatives in the unbroken chain, on the other side of the fault, are at a *much higher* level, and

"Craven fault," in reference to the labours of Professor Phillips, as he had preceded me in a description of the southern end of the fault where it passes into the division of Yorkshire called Craven. With some of its phænomena, in its range from Ingleton to the foot of Stainmoor, I had, however, been familiar for many years; as it crosses my native valley of Dent, about half a mile below the village, dislocating and setting on edge all the lower limestone beds. These "edge-beds," well known to all the quarrymen of the neighbourhood, greatly affect the external features of the country through which they pass.

* Dr. Buckland's observations on the dislocated district near Cross Fell appeared in the Trans. Geol. Soc. 1st Ser. vol. iv. p. 105 *et seq.*

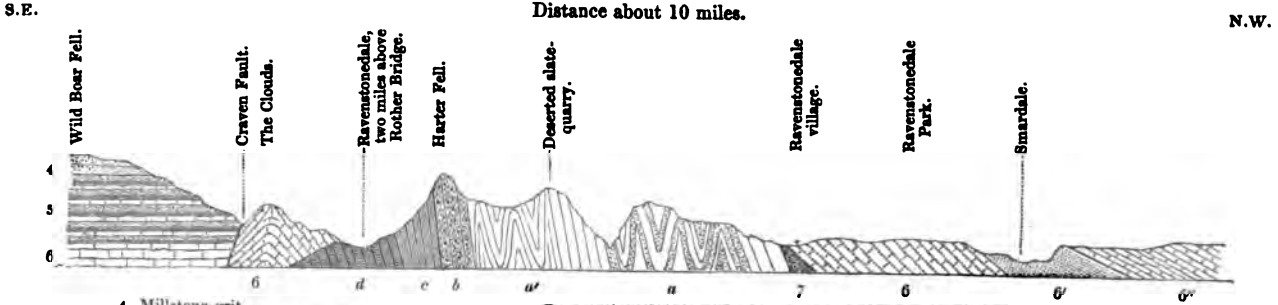
† These facts are noticed and well illustrated in the paper by Professor Phillips, referred to above.

Fig. 1.—*Section from Brough Scar to the Hills S.E. of Kirkby Stephen, crossing the lines of the Pennine and Craven Faults.*



1, 2. } New Red Sandstone.
3. Yellow conglomerates—Permian.
4. Millstone-grit.
5. Alternations of limestone, shale, &c.
5′. Yellow limestone.
5″. Shale.
5‴. Reddish sandstone.
6. Great Scar-limestone.
7. Old Red Sandstone.

Fig. 2.—*Section from Wild Boar Fell, across the Craven Fault, over Ravenstonedale Fells, to Smardale; the two ends of the Section cutting through two distinct branches of the overlying Carboniferous chain.*



4. Millstone-grit.
5. Alternations of limestone, shale, &c.
6″. Overlying member of the Scar-limestone.
6′. Red and variegated sandstone.
6. Great Scar-limestone.
7. Old Red Sandstone.

a. Coarse grit and slate, with calcareous concretions. *Graptolites Ludensis.*
a′. Slate, with conglomerate and calcareous concretions (=Ireleth slates).
b. Coarse, hard grit, alternating with thin beds of slate and flagstone (=Coniston grit).
c. Flagstone with *Cardiola interrupta* and *Graptolites sagittarius* (=Coniston flags).
d. Calcareous slate with Coniston fossils (=Coniston limestone).

over the first crest of the neighbouring mountains. Yet if we ascend to the line of break, which passes through the Scar Limestone, although we find unequivocal marks of dislocation, we do not find any very great change of level between the limestone beds on the opposite sides of the break. Here, therefore, the great downcast at Brough, although connected with the Pennine fault, is produced mainly by the change of dip, and not by any great downcast at the line of break.

Again, I may appeal to the Black Burton* coal-field, the beds of which exist at a level of 1600 or 1800 feet below that of the top of Ingleborough. It might be said, that in their more natural position they ought to be one or two thousand feet above the top of that mountain; and hence it has been sometimes asserted that the fault which passes at the base of Ingleborough must have produced a downcast of more than 2000 feet. In a certain sense this may be true; for the present anomalous position of the Black Burton coal-field may have been, and probably was, produced by the same kind of disturbing forces which produced the Craven fault. But, in the miner's sense, there is no very great fault at the immediate base of Ingleborough. There are the unequivocal marks of a fracture, and there is a great change of dip on the western side of the line of fracture; but immediately on the opposite sides of the break, there is no great change of level in the corresponding beds. In fact, the position of the coal-field arises from a complication of nearly contemporaneous movements, which have been admirably described by Professor Phillips†, and belong not to the discussions of this paper‡.

I have extended the section above-noticed (fig. 1) across the low country between Brough and Kirkby Stephen, to show the effects both of the Pennine and Craven faults: but I have drawn the line in such a manner as to leave out some very confused masses of carboniferous rocks which have been thrown down, in most perplexing confusion, into the upper part of the valley, near the intersection of the two lines of fracture. And I may here remark, as I have done in a former paper, that the magnesian conglomerates, close to Brough, have been tilted, by the action of the Pennine fault, in the same manner as the carboniferous beds on which they rest; whilst the same conglomerates near Kirkby Stephen rest almost horizontally on the edges of the beds which have been tilted by the action of the Craven fault: and hence we may conclude, that the two faults, although both pro-

* See Sections, Trans. Geol. Soc. 2nd Ser. vol. iv. pl. 5. fig. 3; and Phil. Geol. Yorksh. pl. 24. fig. 1; and Map of the Craven District, Trans. Geol. Soc. 2nd Ser. vol. iii. pl. 2.

† See Illust. Geol. Yorkshire, Part 2. p. 126 *et seq.*; and Section No. 1. pl. 24.

‡ I have been informed by some of the old miners in the Black Burton coal-field, that many years since, when they attempted to push their works towards Ingleton, the beds became utterly confused and broken, and that in one place they became nearly perpendicular, and were consequently deserted. Professor Phillips has indeed proved that this coal-field takes not its dip and rise from the limestone immediately on the west side of the Craven fault, but from another highly inclined calcareous chain (Report Lancaster Mining Company, 4to, 1837). There are several great breaks and downcasts between Ingleton and Black Burton, considerably to the west of the great Craven fault.

duced near the end of the palæozoic period, were not strictly contemporaneous—the Craven fault being the older of the two.

The previous remarks may help to prevent any mistake from the use of the word *fault* in the sense in which it has been applied to the Craven and Pennine faults. To describe faults of this kind, we want some new technical word. They are neither anticlinals nor synclinals; nor are they *faults* in the technical sense of the word. The word *break*, if geologists would consent to use that word technically, might perhaps serve for their designation.

In a fault of the normal kind, the downcast is almost universally continued on one side of the line of break: but along the line of the Craven fault this is by no means the case. Its effects near Kirkby Stephen are seen in the previous section, fig. 1; and they produce, on the whole, a great downcast of the masses on the west side; not, however, in all cases, a downcast *immediately* on the west side of the break. But through Ravenstonedale, the valleys of Sedbergh and Dent, and the valley between Dent and Kirkby Lonsdale (Barbondale), the effects are extremely complicated; being interrupted or modified by the immediate contact of the Cambrian and Silurian rocks*. But where the line of dislocation emerges from among the older mountains, for example near Ingleton, we again see the marks of very complicated movements,—producing, on the whole, a great downcast on the western side.

Lastly, I would remark that the older rocks were consolidated and elevated before the epoch of the Craven and Pennine faults; and that these lines of fault were probably not so much produced by well-defined axes of elevation, as by unequal pressure arising from a very uneven surface of the older strata, urged upwards by new forces of elevation, and not acting on single lines, but affecting large tracts of country at the same moment. In confirmation of this view, I may further remark, that the breaks of the carboniferous strata along these lines of fault do not *always* appear to pass downwards into the Cambrian and Silurian strata, on which the carboniferous mountains rest. If this conclusion be confirmed, it will give us an additional reason for using some new technical word to describe a fault which only affects the upper beds of a great vertical section, without much affecting the lower beds.

In a former paper, published in the Journal of the Society†, I have shown that a series of beds—the exact equivalents of the Coniston limestone—range through a part of Ravenstonedale, down the valley of Sedbergh‡, and thence into the valley of Dent, on a line which passes a little on the west side of the Craven fault. This might suggest the conclusion, that the same elevatory movements which pro-

* For details see the Papers previously referred to; and Phillips, *loc. cit.* pl. 24. fig. 14.

† Quart. Journ. Geol. Soc. vol. ii. p. 120.

‡ Down a part of the valley of Sedbergh the range of the Coniston limestone is concealed under the conglomerates of the Old-red-sandstone: but the presence of the limestone, immediately under the conglomerates, is almost demonstrated by the very numerous calcareous pebbles, containing fine Coniston fossils, which are found dispersed through these conglomerates.

duced the Craven fault had also brought up the Coniston limestone in the places above indicated. I do not, however, think that this conclusion would be true; for we have a perfect proof, in numberless sections, that all the older rocks were elevated, contorted, and solidified *before* the existence of the carboniferous limestone; and hence I should conclude, that there was an ancient ridge of hills, partly perhaps subaërial and partly submarine, striking nearly in the actual direction of the Craven fault, and that the carboniferous limestone was afterwards deposited partly over, and partly abutting against this ancient ridge; hence, that during a subsequent period of elevation, this ancient ridge may not only have mechanically produced the fractures of the Craven fault, but also may have defined its direction: in other words, that the Coniston limestone and the associated rocks were the mechanical implements which produced the Craven fault; and that this fault had very little effect upon the relative position of these rocks, and comparatively little effect upon their elevation.

This limitation must not, however, be carried too far. The older rocks may have been, and probably were rent asunder in many places along the line of disturbance which produced the Craven fault; and we have proof positive that some great cross-fractures, which appear to be connected with it, have affected the older rocks as much as the carboniferous limestone which rests upon them. A fine example of this kind is seen below Horton in Ribblesdale, and is represented in one of the accompanying sections (fig. 5, p. 47)*. Whatever may be thought of the previous speculations, it appears certain that while the Craven fault was in progress of formation, many cross-fractures interrupted the continuity of the carboniferous beds, and prepared the way for a series of lateral valleys, such as those on both sides of Ingleborough, and those between Clapham and Horton in Ribblesdale. It is to these lateral valleys that we owe our knowledge of a series of old and highly inclined rocks, which form the base of the carboniferous chain in the neighbouring parts of Yorkshire. In proceeding to notice some of the older rocks which break out near the line of the Craven fault, I shall begin with a section through some of the hills of Ravenstonedale†, which I visited during the past summer; then (passing over the corresponding sections in the valleys of Sedbergh and Dent, inasmuch as I have in those places nothing to add to sections I have already published‡) proceed to describe the sections near Ingleton, and lastly the sections between Clapham and Horton§. The latter sections have been well described by Professor Phillips‖; but at the time his memoir was written, it was impossible for him to determine the place of the older rocks in the Palæozoic series, as no typical groups were then established. My object is to avoid unnecessary details, to take for granted what he has proved, and to produce some

* The cross-fault here alluded to has been well explained and represented by Professor Phillips, Trans. Geol. Soc. 2nd Ser. vol. iii. p. 13, and Section.

† See also Sections, fig. 9, &c., Trans. Geol. Soc. 2nd Ser. vol. iv. pl. 6.

‡ See Quart. Journ. Geol. Soc. vol. ii. p. 120 and 121.

§ See also the Paper and Sections by the Author, Trans. Geol. Soc. 2nd Ser. vol. iv. Part 1.

‖ Trans. Geol. Soc. 2nd Ser. vol. iii.

new evidence which fell under my observation during the past summer, and seemed to determine very nearly the palæozoic place of the older strata near Ingleton and Horton in Ribblesdale.

Ravenstonedale Section. Fig. 2, p. 37.—This section commences with the horizontal beds of Wild Boar Fell, the highest of which belong to the Millstone Grit; it then crosses the Craven fault, and the dislocated masses of limestone, on its western side, which come down to the road called Ravenstonedale Street, and abut unconformably against a series of calcareous slates that are filled with Coniston-limestone fossils. It then passes over the high ridge of Harter Fell, and thence descends to Ravenstonedale Town, and over the long limestone ridge of Ravenstonedale Park as far as the very remarkable transverse gorge which conveys the waters through Smardale into the basin of the Eden. This line makes during its course a considerable bend, so that it may intersect the successive groups of rock in a direction nearly transverse to their strike.

(1.) I profess not in this paper to describe the calcareous chain at the S.E. end of the section; but I may remark, that the passage of the Craven fault produces a very complicated series of disturbances, which I have here very inadequately represented,—that the "edge-beds," called The Clouds (see fig. 2), are above the natural level of the great Scar-limestone,—that the line of break first produces an upcast on the west side, and then, through the intervention of an anticlinal, brings the same beds to a lower level. The immediate presence of the older chain makes it impossible for the dislocated limestone to descend to a much lower level. It has first been broken and elevated by the action of the Craven fault, and then jammed between the two mountain chains, nearly in the manner here represented.

(2.) The Coniston limestone group (fig. 2, *d*) has been described in a previous paper*.

(3.) The S.E. flank of Harter Fell is made up of earthy slates and flagstones (fig. 2, *c*), some of which are calcareous. The beds are much covered with overshot matter, but contain *Graptolites sagittarius*† and *Cardiola interrupta*. These are the exact equivalent of the Coniston flags.

(4.) The hard "Coniston grits" (fig. 2, *b*) are next seen in a very characteristic form, not far from the crest of Harter Fell. I had before traced this remarkable group as far as Cautley Crags, and I have now completed its range by tracing it from Cautley Crags through the south end of the Screes; thence, across Winsterdale, to a high mountain ridge called Adamthwaite Bank; and lastly to the north flank of Harter Fell. It is chiefly composed of hard grey grits, which alternate with thin bands of slate and flagstone, sometimes showing cleavage-planes; and the harder and coarser grits are often marked by spherical concretions, which sometimes are hard and stand out in relief; but commonly are more or less earthy and decomposing, and have been weathered out of the hard grits.

* See Quart. Journ. Geol. Soc. vol. ii. p. 108 *et seq.*

† I believe that in a former paper (*loc. cit.*) this species was mistaken for *Graptolites Ludensis*.

(5.) Over the preceding group comes a series of beds (fig. 2, *a'*, *a*) which, with numerous undulations, breaks, and partial changes of strike, descend to, and pass under, the Carboniferous Limestone. The rocks are in many places deeply covered by the bog-earth of the mountains; but some beds are seen in the watercourses with a good transverse cleavage, and among them are some old deserted slate-quarries, in which the cleavage-planes are beautifully marked by the laminæ of deposit. The slates were found to be worthless; as, indeed, is generally the case where the laminæ of deposit are very near together on the cleavage-planes. The slates are repeated by undulations; and in a deep watercourse, called Lang Gill, we found associated with them a fine conglomerate with calcareous concretions and numerous veins of calc-spar. Phænomena of a similar kind are found in Howgill Fells; and the whole group deserves notice, as it is in the exact geological position of the well-known Ireleth slate-quarries. Farther down (in a watercourse called Gaze Gill) were numberless alternations of coarse grit and slate (fig. 2, *a*). This system was much broken, the strike was continually shifting, and the beds were sometimes very highly inclined. On reaching a still lower level, the prevailing dip was about N. or N. by E., and the beds became gradually less inclined as they descended towards the limestone. In this part of the series were some beautifully striped slates; and among the more earthy beds were some rare instances of septarian balls with calcareous veins. The only fossil found among them was a specimen of *Graptolites Ludensis*.

Making a traverse over the moor-lands, and descending from the old slate-quarries above-noticed by Wygarth Gill, there is a still better section of the group under notice. The beds immediately overlying the quarry-rock are concealed, but in Wygarth Gill we first found a series of brown and rather earthy flagstones, alternating with whet-stone-slate and with masses of hard blue flagstone containing concretions more or less calcareous. Farther down are beds of hard grey gritstone, alternating with flagstone. The beds are repeated by numerous undulations, but gradually acquire a more steady dip, nearly true north, and at an angle of about 60°. In the flagstones of this part of the series are many fossils, which, as a group, are perfectly identical with the fossils in the corresponding beds (over the hard grits) in Howgill Fells. We have here the beautiful small *Pterinea tenuistriata* of Howgill Fells in very great abundance. Among the fossils was a new species of *Aspidaria*, which will be figured in the 'Cambridge Fasciculus,' now in the press.

I had never before examined this line of section, which is, on several accounts, of great interest, as it cuts through the north-eastern protuberance of Ravenstonedale Fells, where two lines of elevation (one striking about N.N.E., and the other nearly east and west) run together. The beds above-described seem to have been broken, crumpled up, and contorted between these two axes of disturbance; producing that protuberance in the mountain-cluster, round which the carboniferous limestone of Ravenstonedale is wrapped, after it diverges (towards the N.W.) from the line of the Craven fault.

But the great group (fig. 2, *a*, *a'*), however much disturbed, is in its true geological order in the series.

At Intack Brow are traces of the conglomerates of the old-red-sandstone; almost buried, however, under great masses of drifted matter which has descended from the mountains. Next comes the lowest group of the carboniferous limestone, which is unusually compact in structure, is rather thin-bedded, and has an aggregate thickness, not, I think, less than that of the great Scar-limestone in the Yorkshire chain between Craven and the foot of Stainmoor*. Over the limestone group comes the red sandstone of Smardale quarries, which is about 120 feet thick (fig. 2, *e*), and well deserves a more detailed description than I can give of it in this paper. It is extensively used for building; and, before I saw the quarries, I had considered it as a most characteristic exhibition of the new-red-sandstone. Its true relations, however, admit of no doubt; for the upper beds of the limestone group, above-noticed, dip under the sandstone at an angle of 10° or 12°. And about 200 yards below the quarry, the red sandstone is, in its turn, seen to dip under higher beds of limestone which abound with characteristic carboniferous fossils. The bottom beds of the sandstone are reddish-grey, flaggy, and calcareous. Then follows a series of beds of a grey, reddish-grey, variegated, and of a dark brick-red colour. Some of these beds are thin, and form a flagstone, the beds of which are separated by laminæ of cream-coloured marl; and on the surfaces of such beds are, here and there, beautiful impressions of *Fuci*, and perhaps of *Annellides*. Other beds show the ripple-mark in great perfection, and obscure impressions of undescribed plants, identical with some that are seen among the grits alternating with the limestone in Lower Teesdale. Some of the brick-red beds are of great thickness, and among them are thin bands of a red conglomerate; but the thickness of the beds is seldom continuous for many yards. All the beds are more or less variegated by irregular yellowish blotches, such as we so constantly see in true new-red-sandstone, and in the triassic groups. The fragments of plants, in whatever bed they appear, are generally too ill-preserved to show any good specific characters.

The points deserving of remark in the previous section are:—1. The peculiar character of the disturbance produced by the Craven fault;—2. The good normal series from the Coniston limestone to the Ireleth slates, &c.;—3. The great mineral change in the carboniferous deposits at the two ends of the section.

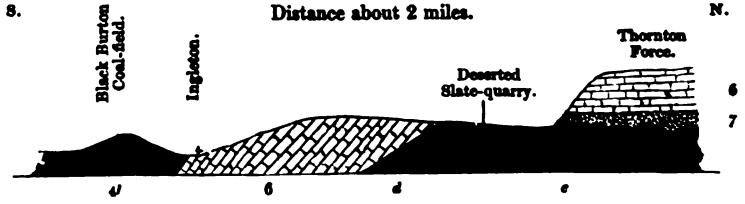
Sections of Thornton Beck and Ingleton Beck.—So far as regards the relative position of the several groups, both of these sections were correctly described by Mr. Phillips in a paper before alluded to†.

* Commencing with the calcareous mountains in the valley of the Ure, or of the Ribble, we have a great uniformity of structure until we reach the neighbourhood of Kirkby Stephen and Brough; but we lose this uniformity in following the Pennine chain northwards from Brough; and we find as great a change while following the calcareous ridges which skirt the north flanks of the Cumbrian mountains. As they approach the west coast of Cumberland, they become very degenerate in thickness.

† Trans. Geol. Soc. 2nd Ser. vol. iii.

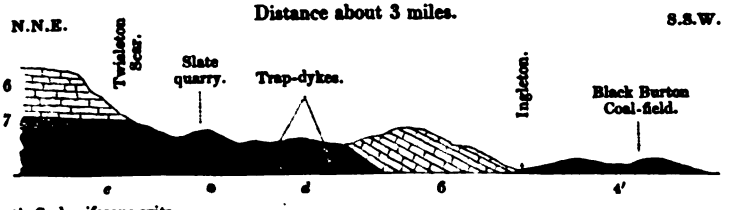
A great spur of the Scar Limestone runs down from Whernside to the scar above Twisleton, forming the separation between Chapel le Dale and Kingsdale. The Thornton section (fig. 3) begins at the

Fig. 3.—*Section from Ingleton to Thornton Force.*



4'. Carboniferous grits.
6. Great Scar-limestone.
7. Old Red [the thickness of this calcareous conglomerate is exaggerated in this Section].
d. Calcareous slate, here and there passing into concretionary limestone, (=Coniston limestone).
e. Greenish slates, alternating with very hard greenish-grey beds of gritstone, *grovine*. Calliard, (=Chloritic Slates of Cumberland and Westmoreland, underlying the Coniston limestone).

Fig. 4.—*Section from Twisleton Scar to Ingleton.*



4'. Carboniferous grits.
6. Great Scar-limestone.
7. Old Red Conglomerate.
d. Calcareous slate with *Orthis Actonia*, &c. (as in fig. 3), penetrated by two veins of felspathic rock [much exaggerated in the Section].
e. Greenish slate (as in fig. 3).

foot of Kingsdale, crosses the Craven fault, and then passes, over the dislocated limestone, to the beds which are prolonged into the Black Burton coal-field. The Ingleton Beck section (fig. 4) crosses the same groups of strata; and, if pictorially represented, would show a deep gorge cutting through the slate-quarries. In fact, the section descends from the great Scar Limestone to the slate-quarries on the west side of the rivulet; but the quarries cross the rivulet, and the section is then taken up (at about a hundred yards distance) on the opposite side, and so taken down to Ingleton, on a nearly parallel line. There is, however, no ambiguity whatsoever in the order of superposition, which is correctly given in the section (fig. 4). The dips are the same in the two sections under notice*, but they are represented, as they are seen in nature, from opposite points of view.

(1.) At the north end of the two sections the Scar-limestone is nearly horizontal, and the upper surface of the slate groups has been worn down to a nearly horizontal surface.

* The mean dip being about S.W. or S.W. by S., and at a great angle.

(2.) At Thornton Force* are some traces of calcareous conglomerates immediately under, and partly penetrating, the bottom beds of limestone. They seem to represent the old-red-sandstone in a very degenerate form; and they disappear in some of the neighbouring sections. Indeed, throughout the North of England, the old-red-sandstone, even when developed on a far greater scale, is generally seen in discontinuous masses.

(3.) Next we have a series of beds (figs. 3 and 4, *e*) rising from beneath the terrace of limestone and conglomerate, and composed of hard gritty greywacké (provincially called *calliard*), alternating indefinitely with slaty and flaggy beds, which show, here and there, traces of transverse cleavage-planes. The dip is south-westerly and at a high angle; and near the end of the group the beds become almost vertical, and so fissile, that large slate-quarries have been opened in them. The quarries on the Thornton Beck section are spoiled by joints and fractures, and are now deserted; but the quarries on both sides of the other rivulet (Ingleton Beck) are still worked extensively. The slates are coarser than the fine greenish-blue slates of the central group of Cumberland, but resemble them in colour. Some of them are marked with beautiful dendritic coverings of pyrites, and occasionally studded with large bright cubes of that mineral. Good sound roofing-slates are, however, obtained without any taint from pyrites. The slaty planes are vertical, and exactly parallel to hard beds of *calliard* which rise at their side; and hence it follows that the planes of fission are parallel to the original laminæ of deposit. But as these Ingleton slates are sometimes marked by numerous parallel stripes or striæ, I at first concluded that these stripes must represent the lines of deposit, while the great fissile planes represented a regular transverse and nearly vertical *cleavage*. In this I was, however, mistaken. In these slates the great smooth planes, from which the rock derives its value, are parallel to the bedding; and the stripes upon these slaty planes represent the intersection of a true system of transverse cleavage-planes. I never remember to have seen any structure like this in the old quarries of North Wales, Westmoreland, or Cumberland; but I have seen some parallel instances in Devonshire and Cornwall. Taking all the series above-described as a group, and judging of it only by its mineral character, its hardness, and above all by its prevailing chloritic tint, I should not have hesitated in classing it, provisionally, with some of the coarser slates, in the central group of Cumberland, under the Coniston limestone.

(4.) Further down the two rivulets, and overlying the rock of the slate-quarries, are some coarser and less fissile beds (figs. 3 and 4, *d*). At a very short distance they become slightly puckered by an intermixture of very irregular calcareous concretions, and it deserves remark, that these calcareous and very irregular portions are chiefly arranged upon ill-defined cleavage-planes, and not generally on the

* A pictorial representation of Thornton Force is given in Phillips's Geol. Yorkshire, pl. 23.

true laminæ of deposit*. In the Thornton section, the upper part of this group (just where it sinks under the dislocated beds of the great Scar-limestone) passes into a mass of dolomitic limestone mixed with shale and flagstone. It contains a few Encrinite-stems, obscure Corals, and Shells of which the species could not be determined. But, passing over to the other section below the Ingleton slate-quarries, we find the same group, which is more widely expanded, probably in consequence of the transverse and unconformable position of the overlying Scar-limestone. The whole length of the group is not, however, more than a few hundred feet; and it is intersected by two dykes, chiefly composed of red felspar and black mica, which, if I mistake not, run together in the higher part of the neighbouring hill †. The whole group is, like that of the other section, more or less calcareous; and the calcareous matter is arranged in a similar manner; but no part of it passes, in mass, into what might be called a dolomitic limestone. The most calcareous portions are near the upper dyke; and from these (helped by the practised hand of my friend John Ruthven) I obtained, at length, a number of very obscure fossils, and among the fossils a few species which seemed to belong to the series of the Coniston limestone. They have since my return been examined by Professor M'Coy, who identifies the following species:—

Stenopora fibrosa, *Goldf. sp.* (ranging from the Bala to the Lower Carboniferous rocks).

Halysites catenulatus, *Martini, sp.* (ranging from the Bala to the Ludlow rocks).

Orthis Actoniæ, *Sow.*; and one or two other ill-defined species of Bivalves.

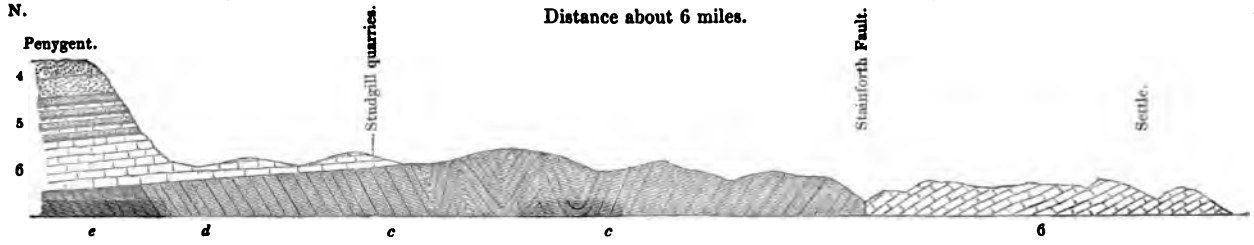
There are, in the great cluster of the Cumbrian mountains, no groups, either above or below that of the Coniston limestone, with a group of fossils like those above-named. This fossil evidence, imperfect though it be, is confirmed by the mineral structure of the neighbouring rocks; and hence we may, I think, safely conclude, that the group here described (from the Ingleton and Thornton sections) is the true equivalent of the Coniston limestone. The overlying beds of the great Scar-limestone, followed by the carboniferous grits, &c., which descend towards the Black Burton coal-field, require no further notice in this place.

Section from the top of Penygent to Settle, on a line nearly parallel to the Valley of the Ribble. Fig. 5.—Were I describing a new country, it would be necessary for me, in this place, to give a map of the singular denudation of the slate-rocks in the valley of the Ribble (above Settle), as well as in some lateral valleys connected with it.

* A most remarkable instance of this structure is seen at the S.W. end of the Coniston limestone after it has passed into Cumberland. One quarry shows a series of calcareous spherical concretions arranged on the planes of cleavage, and not on the true planes of bedding.

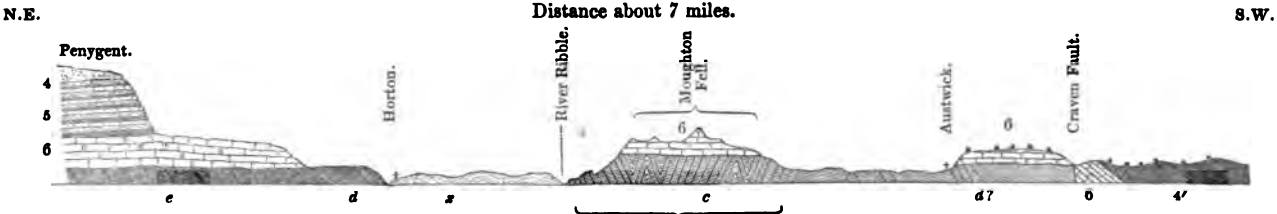
† The structure here noticed is seen in several other dykes near the line of the Craven fault.

Fig. 5.—*Section from Penygent, in Craven, to Settle, across the Stainforth Fault.*



4. Millstone-grit.
5. Alternations of limestone, shale, &c. (=Yordale Series).
6. Great Scar-limestone.
c. Horton flagstone (=Coniston flagstone).
d. Calcareous slate (=Coniston limestone).
e. Greenish slate.

Fig. 6.—*Section from Penygent, over Moughton Fell, to the country near Clapham, crossing the Craven Fault.*



x. Gravel.
4. Millstone-grit.
4'. Carboniferous grits.
5. Alternations of limestone, shale, &c.
6. Great Scar-limestone.

This portion of the Section is N. & S., and represents the flexures of the flagstones as they appear on the eastern side of Moughton Fell, where the details of the bedding are well seen.

c. Flagstone with the mineral character and fossils of the Coniston flags.
d. Grey calcareous concretionary slate [thrown into undulations, not represented in the Section], with Coniston fossils (=Coniston limestone).
e. Greenish slate (as in fig. 3).

But the country is well known, and its superficial features are approximately delineated in Mr. Greenough's Geological Map of England; and a geological map of the tract of country on the line of this section, as well as of the section which immediately follows, has been published in the Geological Transactions*, in illustration of a paper by Mr. Phillips, before alluded to; and to this map I may refer the reader.

The carboniferous and nearly horizontal rocks of Penygent are well known. The top of the mountain represents a part of the Millstone-grit series (see fig. 5). In the steep brows below, we have alternations of limestone, sandstone, and shale (the *Limestone Shale* of Derbyshire or the *Fordale Series* of Phillips†). Near the base of the mountain is the great Scar-limestone, overlying (as in the two former sections, figs. 3 & 4) the highly-inclined beds of older slate-rocks (fig. 5, *d*, *e*). These older rocks have a structure almost identical with that of the rocks under Thornton Force and Twisleton Scar. Over them are beds of the Horton flagstone (fig. 5, *c*); and at Studgill, about a mile below Horton, some of the beds are covered by innumerable specimens of *Graptolites sagittarius*, which fossil I had formerly mistaken for *Graptolites Ludensis*. But I profess not to describe the section in any detail, as I made no observations worth recording in a traverse down the east side of the Ribble. My only object in giving this (partly ideal) section is to show the grand cross-fault, at Stainforth, which brings down the great Scar-limestone, alters the superficial features of the country, and shuts out the slate-rocks from all the lower parts of the valley.

Section from the top of Penygent, in Craven, over Moughton Fell, thence over the calcareous ridge west of Austwick, and across the line of the Craven fault to the plains immediately south of Clapham. Fig. 6, p. 47.—1. The carboniferous, and nearly horizontal, strata of Penygent (figs. 5 & 6, 4, 5, 6) have been just noticed.

2. At Dowgill Scar, a few hundred yards above the village of Horton, the slate-rocks break out at the base of the Scar Limestone; and, at the spots where I examined the junction of the two systems, there was no trace of any intervening conglomerates to represent the old-red-sandstone. This slate-group, although partially repeated by undulations, is of considerable thickness; but it disappears under the alluvion of the valley before we reach the village. I had many times, before last summer, seen these beds, but I never before examined them carefully, or with any view of comparing them with other deposits of the same age. Considered as a group, I was at once struck with their resemblance to the upper portion of the old groups of rock in the two preceding sections (of Thornton Beck and Ingleton Beck, figs. 3 & 4), between the slate-quarries and the spots where the slates plunge under the tilted beds of the Scar-limestone. For in this part of the Horton rivulet we remark the same frequent appearance of chloritic colour, the same hard greenish-blue *calliards*, the same imperfect slaty cleavage, and a similar aggregation of calcareous matter

* 2 Ser. vol. iii.

† See Illustr. Geol. Yorkshire, Part 2.

in some of the fissile beds. Indeed, had not the great Scar-limestone been close at hand, I believe quarries might have been opened in some parts of these older rocks sufficiently calcareous to have been profitably burnt for lime.

Taking the group in ascending order, we first meet with some hard, ferruginous, quartzose beds very near the Scar-limestone. These are followed by bluish-green ragstone and coarse slate. Next, in ascending order, come grey calcareous slates, and flagstones with an obscure transverse cleavage (fig. 6, *d*). These abound in calcareous concretions, and rise in great flaky masses, some of which are penetrated by numerous calcareous veins; they contain numerous fossils, generally ill-preserved. Farther down the rivulet the harder, greenish, and less calcareous bands reappear, but are covered up by the drifted matter of the valley.

The whole group exposed is of considerable thickness, although, partially, repeated by faults and undulations; and its general position among the neighbouring rocks may be collected from the following facts:—First, where the beds emerge from under the horizontal limestone, they dip true S. ∠ 30°. This continues some distance, after which the beds dip 70° W. of Mag. S. ∠ 50°. Then comes a break among the strata, beyond which the beds for a short distance dip 70° E. of Mag. N. ∠ 30°. But they are soon reversed, and dip true S.; and near the extreme end of the section, where the slates disappear, the dip is to a point a few degrees west of true south, at angles varying from 60° to 45°.

The preceding notes may help to show what is the position of the group I am noticing, and its analogies with other groups in the previous sections; but the age of the group must mainly depend on the fossil evidence; and this is not wanting. Assisted by my friend John Ruthven, I carefully turned over and broke up the more calcareous beds and obtained from them the following species:—

Calymene brevicapitata, *Portlock*; a Bala species.
Zethus atractopyge, *M'Coy*; a Bala species.
Leptæna sericea, *Sow.*
Strophomena pecten, *Linn. sp.*; Bala and Wenlock.
Orthis vespertilio, *Sow.*; Bala, &c.
—— Actoniæ, *Sow.*; Bala, &c.
—— parva, *Pand. sp.*; Bala, &c.
—— plicata, *Sow.*; Bala, &c.
—— calligramma, *Dal.*; Bala, &c.
Stenopora fibrosa, *Gold. sp.*; ranging from Bala to Lower Carboniferous (?).
Favosites crassa, *M'Coy*; Bala.
Orthoceras subundulatum, *Münst.*; Bala and Wenlock.
—— primævum, *Forb. sp.*; Bala and Wenlock.

This list is quite conclusive, as nothing resembling it has been found in the North of England except in the Coniston-limestone group.

3. Following the line of section over the wide-spread alluvion of the valley of the Ribble, we reach the bluff escarpment of Moughton

Fell, the upper part of which is composed of nearly horizontal beds of the Scar-limestone, under which are seen the great undulating masses of Horton flagstone. It is obvious, at first sight, that the flagstone must have been elevated, contorted, and solidified; and afterwards planed down by denudation, until, throughout wide spaces, it presented at the bottom of the sea a series of nearly dead levels, on which were gradually accumulated the great reefs and shell-beds of the Scar-limestone.

The base of the Scar-limestone at the S.E. end of Moughton Fell is so far above the level of the corresponding base-line immediately above Horton, that we may suspect the existence of a fault down the valley of the Ribble; or the change of level may perhaps arise from the natural dip of the limestone in the neighbouring district. The line of section does not show the immediate relations of the group last described (*d*) to the Horton flagstone (*c*); but we are not left in doubt, for the calcareous slate-group at the foot of Penygent is (on the left bank of the Ribble) overlaid by the flagstone-series, in which there is a prevailing southern dip, which is continued nearly two miles down the valley below Horton. The Studfield flag-quarries (fig. 5) are in this part of the series; and they may be connected, through quarries opened in Dry-rigg, with the flagstones of Moughton Fell. In this way we obtain a proof that the group of Moughton Fell immediately overlies the calcareous slates (*d*) at the foot of Penygent.

The Horton flagstone has none of the chloritic colour which distinguishes the lower group, and in this respect it resembles the Coniston flagstone, to which it offers many near analogies. It is, however, connected physically, through the alternations of hard beds of grey calliard, with the lower group; and it is not, I believe, possible to define the exact line between them where they exist in continuity. The flagstones follow the laminations of deposit, are of excellent quality, and may be obtained of enormous size. Generally, except where they pass into the condition of a grit, they show cleavage-planes, which sometimes (though rarely) produce a striation on the surfaces of the flags and injure their quality; but no slates are obtained from these cleavage-planes.

I do not wish to describe in much detail a group that has been well described by Professor Phillips; but the following short notes, made on the spot, may be worth recording, as they give the evidence for some of the flexures delineated on the accompanying section, fig. 6.

1. Crossing from Horton to the northern flag-quarry of Moughton Fell, we first traversed a series of coarse slates and hard grey grits (*calliards* of the quarrymen) dipping nearly south. At the quarry the great flagstone dipped 20° W. of Mag. S. ∠ 42°. Many of these beds were marked by a cleavage-plane striking 40° E. of Mag. South, and dipping at an angle of more than 80°, to a point 40° S. of Mag. W. At a short distance the dip of the flags was 30° W. of Mag. S. ∠ 50°; and here were cleavage-planes inclined at about 35° to the planes of stratification. So far as was observed, there did not seem to be much constancy either in the strike or inclination of these cleavage-planes, and the quarrymen turn them to no use, the flags

being raised from the planes of bedding. Many of the beds show impressions of ill-preserved *Orthoceratites*, of which the septa are occasionally visible, and many of them show traces of *Graptolites sagittarius*. Impressions of small Bivalve Shells were not rare, but none of them were sufficiently well-preserved to show specific characters.

At the second great quarry (further to the S.E.), a fine striped flagstone is worked close up to the horizontal limestone. It dips 30° E. of Mag. S. at an angle of 35°. Immediately beyond this quarry is a synclinal line, on the other side of which the dip is 30° E. of Mag. N. Then an anticlinal brings the beds again into the southern dip, beyond which, in a great hollow of the mountain-side, the beds are again reversed, dipping at an angle of 70° to a point 45° E. of Mag. N.; and this northern dip is continued round the S.E. end of Moughton Fell. It is also continued into the Dry-rigg quarries, where the beds dip 45° E. of Mag. N. at an angle of 78°. It is through these quarries, as before stated, that we are enabled to connect the flagstones of Moughton Fell with the corresponding beds on the east side of the Ribble.

In the flagstone series we sometimes observe numerous dip-joints that are coated with calcareous spar; and we occasionally meet with spherical concretions of considerable size; in the Dry-rigg quarries the concretions abound so much as to disfigure the flagstone, and make many slabs of it unfit for use. Sometimes they are hard and calcareous; sometimes soft, earthy, and ferruginous; and not unfrequently they are in the condition of a light porous mass (commonly called "rotten-stone") from which the calcareous matter has almost entirely disappeared. But in almost all instances they were, I believe, originally calcareous, and were aggregated about some extraneous body, such as a shell or coral. Similar concretions are occasionally found in the hard gritty masses associated with the flagstones; and they abound in some beds on the east side of the Ribble as we descend towards Stainforth.

From the quarries above-noticed we obtained the following fossils:

Graptolites sagittarius, *Linn. sp.*
Stenopora fibrosa, *Gold. sp.*
Favosites crassa, *M'Coy.*
Orthoceras subundulatum, *Münst.*
—— primævum, *Forbes, sp.*

Of these fossils the first is found at Moughton Fell and Studgill quarries, and the species ranges from the Skiddaw Slate to the Wenlock Shale. The second probably ranges from the Bala to the Lower Carboniferous group. The third is a Bala species. The fourth and fifth seem to range from the Bala group to the Wenlock Shale.

Taking the facts above-stated as our guide, I think we may conclude that the calcareous group under Penygent (fig. 5 & 6, *d*) is the equivalent of the Coniston-limestone group, and that the Horton flagstone (*c*) is the equivalent of the Coniston flagstone; and thus the sections of the Ribble, so far as they go, are in exact correspondence with the previous section of Ravenstonedale (see p. 41).

Should any one ask, whether still higher groups, such as the Coniston grits and the Ireleth slates, may not be represented among the rocks laid bare in some of the valleys of denudation connected with the Ribble, I could not satisfactorily answer the question. For I know little of the sections on the east side of the Ribble; and there is a large spread of slate rocks (laid down by Phillips) in the lateral valley of Stainforth, which I have not visited for more than thirty years. And the slate-rocks break out again (as I have been informed) in the denudations between Malham Tarn and Kilnsea, in a mountain-tract I have never visited. Again, it might be asked whether the flagstones of the Ribble, with their great alternating beds of hard grits (*calliards*), might not represent both the Coniston flags and the Coniston grits? To such a question I might reply, that, while on the spot, I gave it what I thought a fair trial; and that the evidence of the sections seemed to disprove the supposed union of the two deposits; for the calliards appear to abound quite as much in the lower as in the upper part of the great flagstone group.

With every wish to avoid unnecessary details, I must shortly notice some remarkable beds seen (nearly on the line of section) in the flagstone group on the west side of Moughton Fell. We there find (alternating with the harder grits) a kind of whet-slate or flagstone which is divided into rhombohedral solids by two sets of cross-joints. Many of these regular solids have undergone a partial decomposition shown on the planes of fracture by beautiful coloured rings (exactly like those occasionally seen in flint-pebbles); which, commencing irregularly at the outer surfaces, gradually become more symmetrical as they diminish in size and approach the centres of the several solids. The same kind of decomposition, marked by rings of colour, has affected some *large masses* of the Skiddaw slate, and produced coloured lines which might easily be mistaken for the original marks of bedding. And similarly deceptive lines of colour (derived from a decomposition that has commenced from the joints sometimes traversing masses of considerable size) may be seen, though rarely, among the Ireleth slates, and the Silurian flagstones of Leintwardine.

A valley of denudation separates the tabular calcareous cap of Moughton Fell from a corresponding tabular cap that ranges N. and S. from Austwick towards the base of Ingleborough. I had no opportunity (during my last visit) of examining the slate-rocks in the valley between these tabular hills; which I the more regret, as I have been informed by John Ruthven that calcareous slates, with organic remains, were laid bare in some quarries or excavations that were opened a few years since near the village of Austwick. *Provisionally*, therefore, I consider the Coniston limestone as reappearing in the section under the calcareous ridge near the village. This point might, perhaps, be ascertained by a careful examination of the sections in the neighbouring watercourses. But my time was gone, and I had not a single hour to devote to this examination; and the excavations near the village, to my great disappointment, were all filled up.

The remaining part of the section crosses the *Craven fault*, which

I have sketched in from memory, and in accordance with one of the sections given by Phillips*. It is not my object to describe this part of the great fault. Near Austwick it may, I think, be considered as separated into two branches; the main branch ranging by Giggleswick Scar and Settle; the other, and diverging, branch ranging up the Austwick valley, and then striking nearly E. and W., crossing the Ribble (as above indicated in section fig. 6) near Stainforth, and thence bearing towards Malham Moor. If I might hazard a conjecture, I should say that on this line of fault are probably brought out the slate-rocks which appear between Malham Moor and Kilnsea.

One fact more requires notice before I conclude the description of the section. The grear spur of Scar-limestone that descends towards Austwick is not so high as the top of Moughton Fell, but is in part of its range as high as, or higher than, the junction of flagstones and *calliards* of that Fell with the overlying limestone. Now, not only on the sides, but on the very top of the Austwick ridge†, there lie scattered a series of large blocks (see fig. 6) which exactly resemble the hard grits and *calliards* that break out under the crest of Moughton Fell. These blocks are not in an advanced state of decomposition; they clink under the hammer, and they are generally angular, and not at all water-worn. If we leave the hills and cross the comparatively low carboniferous tract that descends towards Benthan, we may see hundreds of erratic blocks of exactly the same character. How have they been transported; and, especially, by what power have they been perched on the calcareous ridge north of Austwick? That enormous masses of limestone and slate have been washed away, and that the Scar-limestone of Penygent, Ingleborough, Moughton Fell, &c., were once continuous, hardly admits of a doubt; but of the vast masses of matter that were carried away when the valleys were excavated nearly into their present forms, we have no vestige whatsoever. All the alluvion of the valleys, and all the erratic drift above alluded to, belong not to an ancient, but to a very recent period.

If it be allowed, that during the glacial period the land was depressed about 1500 feet below its present elevation, the high calcareous chain of Yorkshire may have existed as a series of ridges and islands surrounded by barriers of ice. Year by year the icy barriers may, during summer, have carried off portions of the rock and dropped them at a distance; and while the land was rising to its actual height, it was quite natural, on this hypothesis, that the floating ice-rafts, and the loads they carried, should be stranded on a

* Trans. Geol. Soc. 2 Series, vol. iii. Pl. I. section F.

† Prof. J. Phillips has mentioned the occurrence of the Calliard blocks on Long Scar on the north of the faulted region. From measurements Prof. Phillips has lately made, he finds that Long Scar is higher than the Austwick Scar and much above the Calliard range; its summit is rather less than 1400 feet above the sea. Some of the blocks still remaining are at an elevation of 1260 feet above the sea. The summit of Moughton Fell is 1404 feet above the sea. The surface of the southern limestone band above Austwick and Clapham Lodge (where the blocks are abundant) is about 850 feet above the sea. I am indebted to Prof. Phillips for these measurements.

ridge like that near Austwick. A great current might account for the blocks in the lower country; but a great current (without the intervention of ice) would, I think, very ill explain the position of the blocks on the above-mentioned calcareous ridge. Connected with this question, I may remark that in many parts of the neighbouring chains of Yorkshire there are large erratic blocks of limestone quite as difficult to account for (without the intervention of a glacial hypothesis), as the position of the calliard blocks above Austwick. For example, in my native valley of Dent, on the rugged side of a mountain made up of the Coniston grits, there are one or two great blocks of Scar-limestone, perched on the bare rocks at a level of more than 1000 feet above that of the sea.

From the details of the previous sections it appears, that the Coniston limestone and Coniston flagstone, which form the base of the whole fossiliferous slate-series of Westmoreland, may be clearly traced from Ravenstonedale through the upper part of the Rother, across the valley of Dent, and again from the ravines above Ingleton to Horton in Ribbledale.

In a subsequent paper I hope to show:—(1.) That, agreeably to my first-published opinion, the Coniston limestone is the exact equivalent of the Bala limestone; and not, as I afterwards supposed, of the Caradoc sandstone. This conclusion falls in with the fact, that the Coniston limestone, at its southern end, does not overlie, but is actually interlaced with, the great central group of Cumberland, or the equivalent of the Cambrian. (2.) That the Coniston flagstone (and its equivalent Horton flagstone) may be grouped with the Coniston limestone. (3.) That the Coniston grits are the true equivalents of the Caradoc sandstone. (4.) Hence that the Ireleth slates and the groups above them are the equivalents of the Wenlock shales, &c. of the Silurian system. The limits of this communication preclude me from discussing these questions, which I hope, before long, to resume.

December 17, 1851.

F. Hindmarsh, Esq. was elected a Fellow.

The following communications were read:—

1. *On the* Quader Formation *of* Germany*.

By Dr. H. B. Geinitz.

[Communicated by Sir C. Lyell, F.G.S.]

The north side of the Harts, where the Upper Quader-sandstone is so powerfully developed, has lately thrown a new light on the relations of this rock with the Upper Quader-marl. Professor Beyrich,

* See Quart. Journ. Geol. Soc. vol. vii. Part 2. p. 6–11.

of Berlin, who is now publishing a geological map of the above-mentioned district, lately invited me to re-examine it with him and in company with M. von Strombeck, of Brunswick, and some other geologists.

The Upper Quader-sandstone near Heimburg is bounded by sandy Upper Quader-marl. The greensand, or green sandy marl, above and below the sandstone, has similar characters and the same fossils as the greensand of Aix-la-Chapelle, of the Salzberg near Quedlinburg, and of Kieslingswalda in Silesia; and as the Upper Quader-sandstone itself.

List of the Fossils.

Callianassa antiqua, *Otto.*
—— Faujasi, *Otto.*
Serpula filiformis, *Sow.*
Belemnites quadratus, *Bl.*
Turritella sexlineata, *Röm.*
Rostellaria papilionacea, *Goldf.*
—— vespertilio, *Goldf.*
Cardita Goldfussi, *Müll.* (= Pholadomya caudata, *Röm.*)
Crassatella arcacea, *Röm.*
Venus faba, *Sow.*
Trigonia aliformis, *Park.*
Arca (Cucullæa) glabra, *Sow.*
Pectunculus sublævis, *Sow.*
Cardium Ottoi (C. Ottonis), *Gein.*
Gervillia Solenoides, *Defr.*
Ostrea laciniata, *Nilss.*
etc. etc.

The grey Chalk-marl (Kreide-mergel) of the hill (Schlossberg) at the village of Heimburg, comprising the Trümmer-kalk (the Conglomerate of the Sudmerberg, near Goslar), is connected with the green sandy marl below it by similarity of organic remains, in the same manner as the Upper Quader-sandstone is united with the Upper Quader-marl in one and the same cretaceous series. This series of sandstones (the Lower and Upper Quader of M. Beyrich), greensand and green sandy marls*, and grey and yellow chalk-marls (Kreide-mergel, and the conglomerate of the Sudmerberg with its Maestricht Corals), is the equivalent of the Tuff-chalk of Maestricht, and the Upper Chalk with Firestone of other countries.

I am likewise of opinion, that the Lower Quader-marl (Lower Flags or Marl- and Sandstone-flags, also the Variegated Marl, and Lower Greensand of Essen) is the equivalent of the Lower Quader-sandstone, and not of the Upper or Chalk-flags, which are the equivalents of the Lower Chalk of Kent.

Consequently I obtain the following arrangement of the series:—

I. Upper Quader { 1. Upper Quader-sandstone / 2. Upper Quader-marl } = Upper Chalk.
II. Middle Quadermarl (Pläner-kalk) = Lower Chalk.
III. Lower Quader { 1. Lower Quader-marl / 2. Lower Quader-sandstone } = Tourtia.
IV. Hils-clay = Neocomian.

Professor Beyrich has represented in his Map the Upper Quader in six subdivisions.

* Sand of Münchenhof and of the Salzberg near Quedlinburg, and the flags of the Plattenberg near Blankenburg.

2. *On the* Causes *which may have produced* Changes *in the* Earth's Superficial Temperature. By W. Hopkins, Esq., M.A., F.R.S., Pres. G.S., and Pres. Cambridge Phil. Soc.

Part I.

On the Influence of the Earth's internal Heat, and of the Heat radiating from external Bodies on the Earth's Superficial Temperature.

§ I. *Influence of the Earth's Internal Heat.*

1. The problem of the internal temperature of the earth, and, assuming that temperature to have been formerly much greater than at present, the laws according to which its refrigeration would take place, have exercised the powers of the first mathematicians. The problem which has been actually solved, however, is more simple than the one which the earth really presents to us. The simplest conditions which have been assumed, are those of a sphere of very large dimensions, like the earth, consisting of matter of which the power of transmitting heat (*the conductive power*) is supposed to be the same in every part; also the temperature of the space surrounding the sphere (*the external temperature*) is supposed to remain invariable during the whole term of the sphere's refrigeration. Poisson solved the problem with less restrictive conditions as regards the temperature of the external space, by taking account of the influence of the earth's atmosphere; but he also assumed, like those who had preceded him, the uniformity of the conductive power throughout the cooling mass. It is not likely that this is really the case with the matter composing our globe, and our ignorance on this point might lead to serious error in the determination of the internal temperature at points remote from the earth's surface. But this is more than the mathematician has attempted. He has limited himself to points connected with the temperature at depths beneath the surface of his imaginary sphere very small compared with its radius, and after the lapse of an enormous time since the cooling process commenced. The problem is thus very much simplified, and the results obtained are doubtless approximately the same as those which would result from the supposition of the variability of the conductive power of the mass. It is also important to remark, that the results with which we are here concerned are independent of the *primitive temperature* of the heated sphere. It may have resulted from causes external or internal, and may have been regular or irregular, provided always the time during which the cooling has been proceeding has been of sufficient duration.

2. A thermometer placed a few inches below the surface of the ground will indicate a variable temperature, which will usually arrive at its maximum after noon, and its minimum after midnight. These variations are due to the irregular supply of heat from the sun during the twenty-four hours, and are not sensible at a depth greater than about 2 feet. If a second thermometer be placed at this latter

depth, it will only indicate a variation of temperature proceeding from day to day as the seasons advance; but if the mean of all the observations on each of these thermometers be taken for the whole year, it will be sensibly the same for both, and will give *the earth's mean annual superficial temperature*. If again a third thermometer be placed a few inches above the gronnd, it will indicate the variable temperature of the atmosphere, and the mean of all the observations on this instrument for the whole year will give *the mean annual temperature of the atmosphere*. This mean again will be sensibly the same as the mean results obtained from the two other thermometers, notwithstanding that the laws of variation for the three instruments respectively are so very different. Consequently, *the earth's mean annual superficial temperature is equal to the mean annual temperature of the atmosphere close to the earth's surface*.

Again, if we place a fourth thermometer at a depth greater than about 2 feet, and not exceeding, in this latitude, 60 or 70 feet, it will indicate (like the second of the above-mentioned thermometers) a temperature changing only with the advancing seasons, and (except for depths not much exceeding 2 or 3 feet) with great regularity. If, instead of a single instrument, we should place a series of thermometers at different depths from 2 feet to about 70, their indications would be very different, although all would follow in a similar manner the changing temperature of the seasons. Each would have its maximum and minimum heights during the year, but the times at which these maxima and minima would occur would be different for each instrument. They would be found earliest in the higher instruments (soon after the hottest part of the summer, and the coldest part of the winter respectively), and later in the lower instruments according to their depths. The extent of the oscillations from the highest to the lowest temperatures would also be different for each instrument. It would be greatest for the upper ones and would decrease according to the depth in the lower ones, until at the depth of about 60 or 70 feet the oscillations would be no longer sensible, the instrument always indicating the same invariable temperature.

The *mean annual temperature* indicated by every one of the thermometers above-mentioned at depths less or greater than 2 feet would be nearly the same. Independently of accidental circumstances which might affect those immediately beneath the surface of the ground, these mean temperatures would be rather greater for the lower than for the upper instruments in proportion to their depths, but that given by the lowest one (which would be its stationary temperature) would not exceed the mean temperature given by the upper one, by more than about 1° Fahr.

Finally, let us suppose our series of thermometers continued downwards along the same vertical line, at depths greater than 60 or 70 feet. Each instrument would indicate an unchanging temperature during the whole year, but the greater the depth of the instrument below the earth's surface, the higher would be the temperature indicated by it, the difference between the indications of any two

instruments being proportionate to the difference of their depths. The same law will also hold true for the indications of the thermometers placed at depths less than 60 or 70 feet, provided we take the mean annual temperatures indicated by them instead of their temperatures at any particular time.

Hence, then, omitting always the diurnal and annual variations of temperature, we have the conclusion that *the internal temperature of the earth increases as we descend beneath its surface in the same proportion as the depth.* This is the exact law as determined by the mathematical analysis of the problem, for all depths which are sufficiently small compared with the earth's radius. It might be taken as approximately true for at least 200 or 300 miles, supposing the constitution of the earth to such depths to be similar to that at its surface. Observation has corroborated the truth of the conclusion to all accessible depths, the deviations from the law being considered as due to local causes.

3. The oscillations of temperature above-mentioned within the range of 60 or 70 feet in this latitude, whether diurnal or annual, are due to the irregular supply of heat received from the sun, especially in the higher latitudes. The continuous supply of heat from the sun during an indefinite period has also prevented the mean internal temperature at any point from descending so low as it would have done in the absence of that luminary. Thus the actual temperature of any point within the earth is partly due to the remains of the earth's primitive heat (according to the theory of terrestrial temperature that we are now considering), and partly to the heat received from the sun during the whole term of the earth's refrigeration. Poisson has estimated the part of the earth's superficial mean temperature due to the latter cause at about 43° F. in the latitude of Paris, more than 59° F. at the equator, and less than 25° F. at the poles. These results, however, may be liable to considerable uncertainty. No further alteration can take place from this cause. The part of the superficial temperature due to the primitive heat is determined without any similar uncertainty. It is very small, amounting only to about one-twentieth of a degree of Fahrenheit. It must have been constantly diminishing for an immense period of time, and has now approximated so near to its ultimate limit, that if the earth's refrigeration should continue under the same external conditions as at present, it would require, as shown by Poisson, the enormous period of a hundred thousand millions of years to reduce this small fraction to half its actual value. Hence the mean superficial temperature of the earth, and consequently the mean temperature of the atmosphere in contact with the earth's surface, may be considered as sensibly unalterable for all future time, provided always, that the sun, the earth's atmosphere, and the temperature of surrounding space shall remain unchanged.

4. We are here, however, more immediately concerned with past than future changes. We should not be justified in supposing, from what I have stated respecting the slow future variation of the earth's superficial temperature, that it has been equally slow for an equal period of past time; but still it is highly probable that some millions

of centuries must have elapsed since the mean superficial temperature could have been greater by a single degree than at present, from the operation of the causes we are now discussing, assuming the permanence of the conditions above-mentioned. However imperfect our geological chronology may be, these enormous periods of time seem almost to preclude the possibility of applying this theory to account for the changes of temperature of which we have evidence in the more recent geological periods.

5. There is also another result for which we are indebted to the mathematical solution of the problem of terrestrial temperature. The effect of internal heat on the earth's superficial temperature must have been, during a long period, constantly decreasing, as already stated. Also the rate at which the internal heat decreases as the depth beneath the earth's surface increases, must, for a like period of time, have been constantly decreasing. The present effect of the internal heat, as above-stated, is about $\frac{1}{30}$th of a degreee; and the rate of increase of temperature below the earth's surface is about 1° F. for every 60 feet. Now we learn from mathematical investigation that this effect of the internal heat on the superficial temperature bears a constant ratio to the rate of increase just mentioned. Consequently, knowing this ratio at the present time, we can ascertain the rate at which the temperature must have increased in descending, at any past geological epoch at which the effect of the earth's internal heat on the superficial temperature was of any assigned amount. Thus, when the superficial temperature was raised 1° F., twenty times the present amount, by this cause, the descending rate of increase must have been twenty times as great as at present, about 20° F. for every 60 feet; and, if the superficial temperature were thus raised about 10° F., the temperature at the depth of 60 feet would, according to the same law, exceed 200° F., and all but surface-springs would be springs of boiling water. This physical state of our planet would scarcely perhaps be deemed consistent with the conditions of animal life at the more recent geological epochs.

6. Formerly it was generally supposed that the only changes of climatal conditions which could be recognized by the geologist, were changes from a higher to a lower general temperature on the earth's surface. More accurate geological research, however, has now shown that there has been no such regular descending progression, but that these changes have been to a considerable extent of an oscillatory character, and so far as they may be thus characterized, they cannot of course be accounted for by the earth's internal heat. So far as the effectiveness of this cause on climatal conditions can be recognized, it can only be with reference to periods which, according to the ordinary modes of estimating time, must be considered as of enormous antiquity, whatever portion of the great series of geological events might belong to them. We must manifestly seek for other causes to account for the changes of temperature which mark the more recent geological periods.

§ II. *Influence of Heat radiating from External Bodies.*

7. It has long been an opinion prevalent among philosophers, that the sun, with the stars in general, has a proper motion of his own from one part of space to another; but it is only in recent times that astronomers have been able to offer anything like demonstrative evidence of such being the fact. At present no one, probably, who is prepared to appreciate that evidence will entertain any serious doubts as to the existence of the motion in question. M. Argelander, M. O. Struve, and finally our countryman Mr. Galloway have all arrived at results respecting the instantaneous direction of the sun's motion, which, considering the nature of the problem, present a very striking accordance with each other. M. O. Struve has also calculated the velocity with which the sun is moving. His result is, that if the sun were seen from the mean distance of stars of the first magnitude, he would appear to describe an arc of about $\frac{1}{3}$rd of a second in a year. If this motion were rectilinear and uniform, it would require a period of nearly seven hundred thousand years for the sun to move over a space equal to the mean distance of the stars of the first magnitude from the earth. This result of M. Struve's is probably liable to serious error, but it is not likely, I conceive, that the true motion of the sun can be materially greater than his estimated motion.

There can be no reasonable doubt that the stars are bodies of the same nature as the sun of our own system, so far as regards the emission of heat and light. Thus the stellar region is occupied with innumerable centres of heat, and must at different points have very different degrees of temperature, as measured by a thermometer which should be exposed to the radiation from these different centres. This consideration, combined with that of the proper motion of the solar system from one part of space to another, led Poisson to the opinion that the present internal temperature of the earth was not due to its primitive heat, but to the circumstance of the whole solar system having passed through a region of space of higher temperature than that now occupied by it.

If we consider the subject with reference to unlimited periods of time, it cannot be denied that this may have been a possible source of terrestrial temperatures, although we may at the same time be obliged to reject the theory in its application to the climatal changes of the more recent geological periods. Let us examine how far it will enable us to account for the comparative cold of the glacial epoch in western Europe.

The stellar system, of which our sun must be considered a constituent body, consists of stars generally at such enormous distances from each other, that the region more immediately around each star must derive an exceedingly small quantity of heat from all the other stars, compared with that derived from the one placed in its centre. The earth is placed in a region of this kind with respect to the sun. The general question is—whether the arrangement of the stars with reference to the sun may, at past geological epochs, have so far differed from the present arrangement, as to have altered materially

the temperature of the region in which the earth is placed, immediately surrounding the sun. The question, however, more immediately before us, is restricted to the consideration of the probability of this region having been so much *colder* during the glacial period than at present, as the phænomena of that period would, if thus accounted for, require. This question admits of a very definite answer.

Whatever may be the indefiniteness of geological periods of time, we are not altogether without means of obtaining a rude estimate of the time which must have been required for the production of some of the later geological phænomena. Sir Charles Lyell has estimated the time necessary for the formation of the delta of the Mississippi, and the accumulation of the alluvial matter of the plain above, at about 100,000 years. The Rhone must have been performing incessantly a similar work at the head of the Lake of Geneva, and many other rivers at the heads of many other lakes, probably ever since the glacial period. Can they have been longer in effecting their comparatively minute operations, than the great American river has been performing its great work of deposition? It would seem improbable. But to render our reasonings the more definite, let us suppose 100,000 years to have elapsed since the period of low temperature in western Europe.

The distance which the solar system would traverse in space during that time, with the rate of motion above given, as calculated by M. O. Struve, would be equal to about $\frac{1}{8}$th of the sun's mean distance from the stars of the first magnitude. Conceive an imaginary sphere, having the earth in its centre, and of which this distance should be the radius. Then the question is,—What variation of the temperature due to stellar radiation may there be within this imaginary sphere?

We have no means of estimating the whole effect of the aggregate radiation of all the stars in space; but we know that any *sensible variation* of temperature due to that cause within a limited space like that of our imaginary sphere, must be entirely due to the influence of stars more immediately in its vicinity. Now we know that the effect of radiation from these nearer stars, at their present distances, on the temperature of any point within the solar system, is exceedingly small, and therefore, that the *minimum* temperature at any point within the above-mentioned sphere can differ only by an exceedingly small, and probably inappreciable, quantity from the temperature of the portion of space now occupied by the earth's orbit,—the temperature here spoken of being always understood to be that which is due to stellar, and independent of solar radiation. A similar conclusion would not be necessarily applicable to the *maximum* temperature; because some part of the boundary of any proposed limited space, like that of our imaginary sphere, might so far approximate to one particular star as to come under the influence of a radiation from it, indefinitely greater than that from any other star. With *centres of heat* there must be local spaces of very *high* temperature, but there are no corresponding limited spaces of very *low* temperature, because there are no corresponding *centres of cold*. These

same conclusions would hold true almost in the same degree, if the time since the glacial period, or the velocity with which the sun is moving, be much greater than above supposed. I think it clear, therefore, that the cold of the glacial epoch cannot be attributed to the cause we are now discussing.

8. As far as we are acquainted with the disposition of the stars not very remote from our own position in stellar space, it would seem probable that the distances of the stars from each other are such that there are no points at present among them at which the intensity of radiating heat is comparable to that which the earth derives from the sun, except at points so near to each star that the heat derived from it is incomparably greater than from any other star. Thus, if the earth could derive a degree of heat from stellar radiation comparable with that now derived from the sun, it could only be by her close proximity to some other particular star, leaving the aggregate effect of radiation from the other stars nearly the same as at present. This approximation of position to a single star, however, could not take place consistently with the preservation not only of the remoter bodies of the solar system, but even of the motion of the earth about the sun, according to its present laws.

Suppose our sun should approach a star within the present distance of Neptune. That planet would no longer remain a member of the solar system, and the motions of the other planets would be disturbed in a degree which no one has ever contemplated as probable since the existence of the solar system. But such a star, supposing it to be no larger than the sun, and to emit the same intensity of heat, would not send to the earth much more than one-thousandth part of the heat which she derives from the sun, and would therefore produce only a very small change of terrestrial temperature.

The only case I can conceive which might possibly be consistent with the continued existence of the solar system in nearly its present form, and in which stellar radiation might produce any great effect on terrestrial temperature, would be that in which the sun should be surrounded by an immense group of stars, and that their proximity should be sufficient to give effect to their radiation, while their arrangement should produce a mutual counteraction of their disturbing influences on the planetary motions. But such a group of stars must be sought for in some portion of the stellar space remote from the region which the solar system now occupies, or in a new grouping of the stars by their own proper motions, in the space immediately surrounding that region; and such changes, if they be possible or conceivable at all, must necessarily require periods of time which would render the theory utterly inapplicable to the explanation of the changes of temperature at the more recent geological epochs.

Part II.

On the Influence of various Configurations of Land and Sea, and Oceanic Currents, on the Earth's Superficial Temperature.

Having discussed the operation of internal and external causes on the temperature of the surface of the earth, I now proceed to the consideration of the influences of superficial causes depending on the configuration of land and sea, and on the oceanic currents which result from such configuration, or are greatly modified by it. The admirable map of isothermal lines by Humboldt and Dove, embodying, as it does, all the best-established observations on temperature in all the accessible regions of the earth, affords us data for this investigation far superior to all we have hitherto possessed. Every geologist is aware how long and ably Sir Charles Lyell has advocated the efficiency of the above-mentioned causes of change of climatal conditions; but before the publication of this isothermal map, the geologist had no adequate means of estimating numerically the effects which these causes were capable of producing. The want of this quantitative evaluation of the intensity of assigned causes has hitherto necessarily given to the theoretical views founded upon them much of a conjectural character, which it is my object, with the improved means we possess, as far as possible to remove.

Every separate configuration of land and sea which we may suppose to have existed at any assigned geological period would require a separate investigation, in order to ascertain its effect on the climatal conditions of that period. In this paper I shall restrict myself to the examination of those hypothetical cases which, according to the general views of different geologists, may have been actual cases during the later periods of geological history; and my more especial object will be, moreover, to ascertain whether any of these supposed configurations will enable us to account for the cold of the glacial period in our own region of western Europe; and, if so, which of them must be regarded as most effective for this purpose.

9. In examining the course of the isothermal lines for the northern hemisphere, we are at once struck by their extraordinary deviations from parallelism with the equator, which must be considered as their normal type. The most remarkable of these deviations is that which exists in the northern part of the Atlantic and in the adjoining part of the North Sea. (See Map, Plate II.) The isothermals for every month, but especially those for the winter months, have an extraordinary deviation and convexity towards the north. Again, in north-eastern Asia the abnormal courses of these lines are almost equally remarkable. For the winter months, the deviation, and consequent convexity, of the lines is here to the south; while the summer lines deviate, on the contrary, to the north. Deviations also exactly similar to those of north-eastern Asia exist in the northern part of the New Continent. The deviations from the normal types in the southern hemisphere are much smaller, the principal ones

being those on the western coast of South Africa, and the western coast of South America respectively.

The abnormal forms of the isothermals in the northern Atlantic and North Sea are manifestly due principally to the warm waters of the Gulf Stream; those of eastern Asia and North America are attributable to the existence of large masses of land in high northern latitudes; while those above-mentioned in the southern hemisphere are immediately traceable to the influence of well-known ocean-currents setting from the south towards the equator along the coasts of southern Africa and South America. The water of these currents reduces the temperature of those parts of the ocean through which they pass, and consequently also that of the superincumbent atmosphere, and thus causes the isothermals to deviate to the north of their normal positions. Thus an examination of all the principal deviations of the isothermal lines from their normal types leads to the conclusion that ocean-currents and the configuration of the great continents are the principal general causes which produce irregularities in the forms of those lines; and, moreover, a knowledge of these causes enables us to assign to the isothermals their approximate positions in any proposed hypothetical case in which the disposition of land and sea should be different from that which obtains at the present time.

The different hypothetical cases for which I shall endeavour to determine the isothermal lines are the following:—

(1.) The configuration of land and sea the same as at present, but without the Gulf-stream.

(2.) The Gulf-stream the same as at present, except that its progress into the North Sea is supposed to be arrested by a barrier of land, extending from the north of Scotland to Iceland and thence to the coast of Greenland.

(3.) The basin of the Atlantic from the Tropic to the North Sea converted into land, uniting the old and new continents.

(4.) Large portions of the continents of Europe and North America submerged beneath the surface of the ocean, and the Gulf-stream diverted into some other course.

The consideration of these cases will occupy the first Section of this Part of the memoir.

10. The *snow-line*, or that line on the side of a mountain above which the snow never disappears at any season of the year, bears an important relation to glaciers, since it divides that higher region, in which productive agencies prevail in augmenting superficially the mass of a glacier, from the lower region, in which the destructive agencies predominate. It is essential to our investigations to know the vertical distance which existing glaciers usually descend beneath the snow-line, that we may be able to judge by analogy of the probable distances to which ancient glaciers may have descended.

As we ascend from the surface of the earth, the *mean annual temperature* decreases according to laws which have been approximately determined by observation. If this temperature, therefore, at any proposed place be greater than 32° F., we shall only arrive at

this latter temperature at a certain elevation above the earth's surface. A line on the side of a mountain, or an imaginary line in space, along which the *mean annual temperature is* 32° F., I define as the *line of* 32° *F.* Its height can be approximately calculated for any place at which the mean annual temperature is known. In sufficiently low latitudes it will be at a considerable height above the earth's surface, but will descend to the surface along the *mean annual isothermal* of 32° F. as we proceed into higher latitudes. The relative heights of this line and of the snow-line at the present time depend on circumstances. It is essential to ascertain these circumstances and their influence, that we may be the better able to estimate the height of the snow-line in the hypothetical cases which I purpose to consider. We shall then be able, as intimated in the preceding paragraph, to estimate the height above the level of the sea to which the ancient glaciers may have descended. The second Section of this Part will be occupied with the consideration of these points. In the third and final Section I shall offer some observations on the relative claims of the different hypotheses of the first two Sections to form the foundation of geological theories.

§ I. *On the Positions of the Isothermal Lines in the above-mentioned hypothetical cases.*

11. Taking the first case, that of the absence of the Gulf-stream, let us trace the probable course of the January isothermal of 32° F. (see Map). Proceeding from east to west, we observe that it attains its most southerly point on the high table-lands of south-eastern Asia, proceeding thence with a little inclination towards the north until it has passed the Black Sea and arrived at the longitude of 20° E. As far as this point we may assume its position to be unaffected by the influence of the Atlantic waters warmed by the Gulf-stream. This influence, however, begins to show itself immediately to the west of the point above-mentioned, in the irregular and extensive deflection to the northward, which there begins to characterize this isothermal. This deflection is not entirely attributable to the Gulf-stream, for the Atlantic Ocean, independently of any warming currents, would undoubtedly produce some effect in lessening the winter cold of western Europe, and therefore produce northern inflections of the winter isothermals. Another reason for the more northern position of this line in western Europe than in south-eastern Asia is the absence of that high table-land in the former region which characterizes the latter. To represent these influences, I have drawn the isothermal for our supposed case so as to continue to the coast the general northward direction which the actual line acquires about the 20th degree of longitude (see Map). This causes it to meet the Atlantic on the extreme western coast of Brittany. If we should draw the isothermal directly west from the meridian of 20° of long., it would cause the isothermal of about 24° F. to pass through that point of the coast through which the line of 32° F. passes as I have drawn it, so that 8° is thus allowed for the influence of the Atlantic Ocean,

independently of the Gulf-stream, on the mean January temperature about these parts of the coast of western Europe. The actual temperature of the west coast of Brittany for January is about 42° F., instead of 32° F., as it would be in the absence of the Gulf-stream, according to the position of my imaginary isothermal for that case. I am, therefore, thus assigning an amount of 10° F. for the influence of the Gulf-stream on the January temperature of the coast of Brittany. The whole effect, therefore, of the Atlantic with the Gulf-stream on that coast is thus estimated at 18° F.

In traversing North America, the extensive mass of land to the north brings down the winter isothermals again to almost as low latitudes as in eastern Asia. The actual isothermal of 32° F. meets the American coast a little south of Philadelphia, and then pursues a very nearly western course until it reaches the meridian of about 106° W. long., where it begins to be affected by the Pacific Ocean and to deviate considerably to the northward. To complete my hypothetical line of 32° F., I join the point to which we have already traced it on the coast of Brittany with that at which the actual isothermal meets the coast of Philadelphia as just mentioned, the connecting line being slightly convex towards the north on the coast of Europe, and to the south on the coast of America, as is required by the continuity of its curvature. Across America, and to the west of it, the isothermal must manifestly be beyond the influence of the Gulf-stream, and our hypothetical line must consequently coincide with it.

It would appear from the existing isothermals, that the Gulf-stream produces little effect on the temperature, even in winter, on the eastern coast of America, as compared with its effect on the western coast of Europe. There are several causes which may be assigned for this difference. After the stream has passed the straits of Bahama, it passes into an ocean of which the temperature is not much inferior to its own, and more northerly its influence must be in some degree counteracted by the cold current proceeding southward through Davis's Straits. To the influence of these causes may be added that of the west winds which appear to prevail on the eastern coast of America as well as on the western coast of Europe. These, coming from the land in the former case, and from the ocean in the latter, tend to lower the winter temperature on the American, while they raise it on the European coast.

The deflection of the actual January isothermal of 32° to the northward on the western coast of N. America is considerably more rapid than that of my hypothetical line on the western coast of Europe. It also exceeds that of the lines of 41° and 50° more than any mere law of continuity would seem to require. A considerable portion of the deflection is attributable, I doubt not, to local causes. In fact, a considerable current is described as setting northward along that coast from about the 45th degree of latitude, which may probably account for this extra deviation. The remainder must be attributed to the influence of the Pacific Ocean, and would probably accord with the similar deflection which I have given to my hypothe-

tical line as arising from a similar cause on the western coast of Europe.

Supposing the isothermal we have been considering to be correctly drawn for our hypothetical case, there can be no doubt, I conceive, of the approximate accuracy of the neighbouring January isothermals as I have drawn them. In southern Asia they are compressed near to each other by the region of maximum cold which lies in the north-eastern portion of Asia. As they approach the coast of western Europe they will necessarily become more dilated, as I have represented them.

12. Let us now examine the probable position of the isothermals for July in the hypothetical case of the non-existence of the Gulf-stream. These lines, it will be observed, as they now exist, have an extraordinary inflection to the north in north-eastern Asia. As we proceed westward from that region, they take a direction considerably south of west, until they come under the influence of the anomalous temperatures of western Europe. This influence, however, does not sensibly extend so far southward in summer as in winter, on account of the higher temperature of the northern Atlantic in summer. The July isothermal of 63°·5 F., which passes immediately south of London, seems not to feel it in any sensible degree. This isothermal, therefore, and all those to the south of it may be considered to have the same positions in our hypothetical case as in the existing one. Those immediately on the north of the isothermal of 63°·5 must necessarily be approximately parallel to it. We observe also, as these lines approach the coast of America, they suffer an anomalous deflection to the south, due, I imagine, to the polar current setting southwards along that coast from Davis's Straits, the warm season being that in which this cold current would be most felt. I have drawn the isothermals for our supposed case, as independent of these anomalous deviations, and such as their actual positions on the east and west of the region of these irregular influences obviously indicate. It would hence appear, that the Gulf-stream has no sensible influence on the July temperature of London, or of places in western Europe further to the south.

13. We are now prepared to estimate the effect produced by the Gulf-stream on the *mean annual temperature* of any assigned place. The following are the approximate numerical values of the temperatures for January and July, and the mean annual temperature, considered as the mean of those two temperatures, for the Alps, Snowdon, the northern extremity of Scotland, and centre of Iceland; both for the present time, and for our hypothetical case, in which, it will be recollected, the configuration of land and sea is supposed to be the same as at present, but the Gulf-stream not to exist. The temperatures are all determined by Dove's map.

	At present, with the Gulf Stream.	Difference.	Without the Gulf Stream.	Difference.
THE ALPS.				
Temperature for January	38° F.	35°	34° F.	39°
" " July	73		73	
Mean annual temperature	55·5		53·5	
SNOWDON.				
Temperature for January	38 F.	23	23 F.	38
" " July	61		61	
Mean annual temperature	49·5		42	
NORTHERN EXTREMITY OF SCOTLAND.				
Temperature for January	36·5 F.	19·5	12 F.	44
" " July	56		56	
Mean annual temperature	46·25		34	
CENTRE OF ICELAND.				
Temperature for January	30 F.	22	−4 F.	50
" " July	52		46	
Mean	41		21	
Mean annual temperature*	39			

14. The next case I have proposed for discussion is that in which the Gulf-stream should exist, with a barrier of land connecting Scotland with Iceland, and that island with Greenland. Since this barrier would intercept the influx of the Gulf-stream into the North Sea, it would very much reduce the temperature there, and in all the northern parts of Scandinavia. On the other hand, the waters of the Gulf-stream, being now confined to the northern part of the Atlantic, would considerably raise the temperature of that region. According to our preceding estimate, the present increase of mean annual temperature due to the Gulf-stream is as follows:—

18° F. in Iceland; 7°·5 F. at Snowdon;
12°·25 F. in the north of Scotland; 3° F. at the Alps.

The mean annual temperature on the south coast of Iceland is now about 40°. It is, I think, probable that this might be raised by 4° or 5° in the case supposed, which would make it approximate to the mean annual temperature of the English Channel. This effect on the mean temperature would be due principally to the effect on the winter temperature. If this latter were increased 6° or 7°, and the summer temperature 2° or 3°, the January temperature would be nearly uniform (or the January isothermal would run nearly north and south) from Iceland to the latitude of the Alps or central France. The January isothermal of 32° now runs north and south through an equal extent of latitude from a point several degrees north of the Arctic circle to the southern shore of the German Ocean. On the

* This is deduced from the mean of the monthly temperatures. The mean annual temperatures above given for the other cases is almost identical with those deduced from the monthly temperatures. The discrepancy of 3° in the case of Iceland may be attributed to local peculiarities.

north of the barrier, on the contrary, the variation of temperature would be more rapid than at present.

15. The next supposed case is that in which the whole Atlantic, from the equator northward to Greenland, Iceland, and the North Cape, should be converted into land. In this case there would be no reason why the isothermals should not preserve their parallelism, with the exception of merely local deviations, from points near the east coast of Asia to corresponding points near the west coast of North America. Let us first consider the January isothermal of 32° F. in the northern hemisphere.

If we take this line as drawn independently of the disturbing influence of the Gulf-stream, but supposing the Atlantic still to exist, it is characterized by a northward inflection as it approaches the Atlantic, due to the influence of that ocean. In the present case there is no reason for that inflection, and we may assume the isothermal to pass nearly in a straight line from the Black Sea to the point where the actual isothermal of 32° F. meets the coast of America. This will render its course nearly a straight line between the opposite coasts of the single continent into which the two existing continents would be united in the case we are considering. Its course would be very nearly, but not exactly, east and west, reaching a rather lower latitude in Asia than in America, in consequence of the high table-lands of south-eastern Asia.

The three succeeding existing isothermals to the north on Dove's map (those for 23°, 14°, and 5° F.) are very nearly parallel to that of 32°, and equidistant from each other through about 80° of long. in Asia, and through 30° of long. in N. America. In the intermediate space they are inflected to the north by the Atlantic. Their positions in our present hypothetical case would doubtless be approximately determined by substituting straight lines across this intermediate space, for the actual inflected lines. (See Map, Pl. II.)

The present winter isothermals, north of those just mentioned, become more irregular in their course in eastern Asia, as well as in North America. In the former region the distance of successive lines from each other is somewhat less than in the latter, owing to the unsymmetrical position of the region of maximum cold, which, instead of being symmetrically situated round the north pole, inclines considerably towards north-eastern Asia. This position must be due, in great measure, I conceive, to the influence of the North Sea, warmed as it is by the Gulf-stream. In our hypothetical case this cause would be removed, and we may conclude that the region of maximum cold would be situated nearly symmetrically with reference to our one great continent, but inclined from the pole towards that continent, and from the great Pacific Ocean situated on the opposite side of the pole. The probable longitude of its central point would be nearly that of the present western coast of Europe. This would bring the isothermals in our hypothetical case, lying on the north of those already traced, into approximate parallelism with the equator between the eastern coast of Asia and the western coast of America. The distances between them (for such, at least, as should not be too far to the north) would necessarily be much the same as between

those of which the positions have been previously discussed,—the isothermals of 32°, and the three succeeding it to the north.

The approximate positions of the winter isothermals on the south of that of 32°, and in the northern hemisphere, may be easily inferred in like manner. It is not necessary here to discuss them in detail.

Let us now take the July isothermals for the northern hemisphere. In Asia there would seem to be no reason why they should differ materially in the present case from the actually existing lines. West of the meridian of 60° E. the two lines of 36°·5 and 41°, delineated on Dove's map, are manifestly affected by the Gulf-stream. The next to the south, that of 45°·5, together with the two succeeding lines, follow the inflection of the northern coast of Scandinavia, and must be considered as influenced in a small degree by the same cause. If we place them a little more southward, but still allowing for the tendency of the slight northern projection of the continent in that region to inflect these summer isothermals to the north, their positions will be approximately correct for our supposed case. Further west we must destroy the southward inflections produced by the Atlantic, and continue the isothermals almost directly west to the most northern points through which the existing ones pass respectively in the north-western part of N. America, about the meridian of 130° or 140° of W. long.

Again, the isothermals still more to the south may be considered as unaffected by the filling up of the Atlantic, at the points at which they meet the meridians of 60° E. long. (that of the Ural Mountains), and at those of 100° to 120° W. long. Straight lines joining these respectively would represent the isothermals of the intermediate space independently of merely local variations.

Taking the same places as before, we have the following results in the case before us for their temperatures:—

	At present.	Difference.	Old and New Continents united.	Difference.
The Alps.				
Temperature for January	38° F.	35°	14° F.	61°
" " July	73		75	
Mean annual temperature	55·5		44·5	
Snowdon.				
Temperature for January	38 F.	23	−7 F.	73·5
" " July	61		66·5	
Mean annual temperature	49·5		29·75	
Northern Extremity of Scotland.				
Temperature for January	36·5 F.	19·5	−22 F.	84
" " July	56		62	
Mean annual temperature	46·25		20	
Centre of Iceland.				
Temperature for January	30 F.	22	−25 F.	78
" " July	52		53	
Mean annual temperature (deduced from the monthly temperatures)	39		14	

The isothermal of 32° F. would pass nearly through Madrid. The whole climate of western Europe would be converted into an extreme continental climate similar to that of north-eastern Asia at present.

16. The last hypothetical case I propose to consider is that in which all the lower land of Europe should be submerged beneath the surface of the ocean. This tract would comprise all northern Europe except the mountainous parts of Scandinavia; nearly the whole of Russia in Europe, extending southward to the Black Sea; together with Central and Western Europe as far as the Pyrenees, the Alps and the Carpathian Mountains, except those limited ranges of higher land which might still protrude as islands above the surface of the ocean. This space is intended to include all that over which the sea of the period of the Northern Drift must once have extended (supposing the drift to be of submarine origin), together with such further extension southward as may be rendered probable by the configuration of the existing surface of the land. I shall also assume the entire absence of the Gulf-stream. I shall consider hereafter the manner in which this great current may have been arrested, or diverted from its present course.

In discussing the positions of the isothermal lines for the northern hemisphere in this case, we may again commence with the January line of 32° F. There appears no cause for any material alteration in its position in southern Asia east of the meridian of about the 70th degree of longitude. To the west of that meridian the influence of the ocean extending to the Black and Caspian Seas would doubtless begin to deflect it towards the north, and probably somewhat more than I have supposed it to be inflected by the Atlantic, independently of the effect of the Gulf-stream. From the 30th or 40th degree of east longitude it would proceed nearly west, but with a slight deflection to the south, arising from the influence of the land which we may suppose still to exist in Scandinavia, and also from that of the northern continent of Greenland. This would cause the isothermal to intersect the line of the existing French coast about its north-western extremity, the point at which I have before supposed it to be intersected by the line of 32° F. in the absence of the Gulf-stream. (See Map.) In the region of North America the isothermal would depend on the manner in which the Gulf-stream should be diverted from its present course. The neighbouring isothermals would follow the course of that of 32° with approximate parallelism. The July isothermals, which should traverse the sea that we are now supposing to extend nearly as far east as the Ural Mountains, would be deflected southward as they are at present on approaching the shores of western Europe. It will be observed that the July isothermal of 63°·5 intersects the January one of 32° (as I have drawn them for the case previously considered of the absence of the Gulf-stream) at a point very near the extreme western coast of Brittany (art. 11, p. 65). Between this point and the meridian of the Ural Mountains, the January line would lie more to the north and the July one more to the south, by the influence of the extended ocean. The effect, therefore, would be to equalize in a greater degree than at present the summer

and winter temperatures of the tract in the vicinity of the European portions of these lines, but probably without producing any material changes in its mean annual temperature. This tract may be considered as comprising the whole of central Europe, together with its western portion from the Pyrenees to the southern shores of the Baltic. It is the region in which the geologist is more especially interested in tracing the climatal influences of changes in the configuration of the earth's surface. I shall therefore endeavour to ascertain from more general considerations the probable effect of an extended ocean on the *winter*, the *summer*, and the *mean annual temperatures* of the region in question.

17. For this purpose I have deduced from Dove's map the following results respecting these temperatures for the 20th, 30th, 40th, and 50th parallels of latitude in both hemispheres. Each result given for January is the mean of the January temperatures for all places situated under the corresponding parallel of latitude; and each result for July is a similar mean for the July temperatures. The mean of these is assumed to be the approximate value of the mean annual temperature of the different parallels respectively.

Mean Annual Temperatures of different Parallels of Latitude.

Lat. = 20° N.		Diff.	Lat. = 20° S.		Diff.
January mean temp.	68° F.	14°	January mean temp.	78° F.	9°
July " "	82		July " "	71	
Mean annual temp.	75		Mean annual temp.	74·5	
Lat. = 30° N.			**Lat. = 30° S.**		
January mean temp.	58 F.	20°	January mean temp.	75 F.	12°
July " "	78		July " "	63	
Mean annual temp.	68		Mean annual temp.	69	
Lat. = 40° N.			**Lat. = 40° S.**		
January mean temp.	37 F.	35°	January mean temp.	58 F.	9°
July " "	72		July " "	49	
Mean annual temp.	54·5		Mean annual temp.	53·5	
Lat. = 50° N.			**Falkland Islands.*** **Lat. = 50° S.**		
January mean temp.	16 F.	46°	January mean temp.	34 F.	18°
July " "	62		July " "	52	
Mean annual temp.	39		Mean annual temp.	43	

We may first remark the striking equality of mean temperatures in corresponding parallels north and south of the equator as far as the 40th degree of latitude. The small differences indicated by the above numbers are not to be regarded, because they lie within the limits of error to which the numbers themselves must necessarily be subject. In the latitude of 50° N. the severe winter cold of eastern Asia and that of the central portions of the North American continent reduce the mean temperature to more than 4° lower than that

* The isothermal lines for this southern latitude on Dove's map are continued only for short distances to the E. and W. of the Falkland Islands, so that the temperatures here given must not be depended upon for the mean temperatures of the parallel of 50° S. They are probably not far wrong, on account of the great regularity of the neighbouring isothermals.

of the Falkland Islands in 50° S. latitude. But there are only a few observations recorded either of the January or the July temperatures along that southern parallel.

There is, on the contrary, a striking contrast between the northern and southern hemispheres with respect to the differences of summer and winter temperatures. These differences are in all cases considerably greater, and in the higher latitudes much greater, in the northern than in the southern hemisphere.

From these results it would appear, that the greater or less extent of land or sea has very little effect on the mean annual temperature of an entire parallel of latitudes from the equator to about 45° of latitude; and that beyond that parallel the predominance of land diminishes, while that of sea increases the mean annual temperature. Also, that a predominance of sea, in all cases, but especially in the higher latitudes, produces a greater equality of summer and winter temperatures.

18. Again, let us compare the temperatures of different stations along the same parallel of latitude, some of these stations being centrally situated as regards the continents, and others as regards the sea. It should here be remarked that the temperatures of the stations in the Atlantic for the 40th and 50th degrees of latitude must be regarded as partly hypothetical, because I have estimated them independently of the influence of the Gulf-stream. The following table embodies the results, deduced from Dove's map, for different stations on six parallels from that of 20° S. lat. to that of 50° N. lat. inclusive.

Parallel of Latitude.	Longitude.	Temperature.			
		January.	July.	Difference.	Mean.
		° F.	° F.	° F.	° F.
20° S.	23 E. Land	78	71	7	74·5
	20 W. Sea	74·5	67	7·5	70·75
	56 W. Land	78	68	10	73
	140 W. Sea	77	74	3	75·5
10° S.	23 E. Land	78	75	3	76·5
	20 W. Sea	77	74	3	75·5
	56 W. Land	78	75	3	76·5
	140 W. Sea	78	77	1	77·5
20° N.	30 E. Land	65	91	26	78
	40 W. Sea	71	76	5	73·5
	150 W. Sea	71	78·5	7·5	74·75
30° N.	30 E. Land	56	81·5	25·5	68·75
	40 W. Sea	59	73	14	66·25
	150 W. Sea	62	72·5	10·5	67·25
40° N.	48 E. Land	32	79	47	55·5
	40 W. Sea	44	68	24	56
	90 W. Land	31	75	44	53
	170 W. Sea	54	59	5	56·5
50° N.	80 E. Land	0	71	71	35·5
	30 W. Sea	26	61	35	43·5
	90 W. Land	0	61	61	30·5
	150 W. Sea	35	53	18	44

On examining this table, we remark that in latitude 20° N. or 20° S., the mean of the temperatures of the land stations exceeds the mean of the sea stations; and in latitude 30° N. there is a similar small excess. In latitude 40° N. there is no sensible excess, and in latitude 50° N. the mean of the two land stations is about 10° less than that of the sea stations. It would thus appear that the effect of continents within the first 40° of latitude has the effect of increasing slightly the mean annual temperature of the most central parts of such continents, although it would appear from the previous table (art. 17, p. 72) that the existence of such continents within the above latitude has no appreciable effect in elevating the mean annual temperature of the whole parallel. The depression of the mean annual temperature at the land stations, compared with that of the sea stations, in latitude 50°, is large. We might hence be led to conclude that a diminution of land and increase of sea along that parallel, such as would result from the depression of Europe beneath the ocean, would be attended with a considerable increase in mean annual temperature in the region thus become sea. This effect, however, would be very different in different continental regions along the same parallel. The effect would be greatest in the most central parts of the continent, and least in the vicinity of its bounding shores. To find the effect of the submersion of Europe, we may compare the mean annual temperatures at the two sea stations already given on the parallel of 50° with two other land stations on that parallel, one in western Europe (long. 10° E.), and another in eastern Europe (long. 30° E.). The temperatures of these stations (assuming always the absence of the Gulf-stream) will be—

	Long. 10° E.	Diff.	Long. 30° E.	Diff.
January temperature...	25°	40°	14°	54°
July temperature	65		68	
Mean	45		41	

The mean of 45° and 41° is 43°, which is not 1° less than the mean of the two sea stations of the same latitude. This tends to prove that the conversion of Europe into sea would have little effect on the mean annual temperature of those portions of it which lie contiguous to the parallel of 50° latitude, and especially in western Europe, the region, for instance, lying between the parallels of the Alps and the southern shores of the Baltic. At the same time the winter temperature would be increased and that of summer diminished to an equal amount, since their mean remains the same. If we suppose the change in each of these temperatures to be 4° for the station abovementioned (long. 10° E.), we shall have for that station,—

		Diff.
January temperature.....	29°	32°
July „	61	
Mean	45	

At Snowdon, from its greater proximity to the ocean, this change in the summer and winter temperatures will be less. If we suppose it to be 2°, we shall then have for Snowdon (see Table, art. 13, p. 68),—

		Diff.
January temperature.....	25°	34°
July „	59	
Mean.....	42	

This latter mean annual temperature is about 2° higher than that of the south coast of Iceland (see Table, art. 13, p. 68). The difference of summer and winter temperatures, 34°, is greater than for Iceland, where it may be stated generally to be about 18° or 20° only. This actual case, however, presents a good standard of comparison for our hypothetical case. The Falkland Islands, situated in lat. 50° S., and the island of S. Georgia, in lat. 54° S., furnish also good standards of comparison. The conditions of the station above-mentioned in western Europe (long. 10° E.), and Snowdon, of which the latitude is 53° N., would, in the case we are discussing (that of the absence of the Gulf-stream, and the submersion of Europe), far more resemble the actual conditions of all the above places than they do at the present time. We have for the Falkland Islands,—

		Diff.
January temperature.....	52°	18°
July „	34	
Mean.....	43	

This is less by 2° than the estimated mean temperature for the corresponding place (long. 10° E.) in N. lat.; the difference between the winter and summer temperatures is here less by 16° than in the other case. Again, we have for the island of S. Georgia (lat. 54°),—

		Diff.
January temperature.....	45°	14°
*July „	31	
Mean.....	38	

Here the mean temperature is 4° less than the estimated mean temperature of Snowdon; and the approximation to uniformity of temperature throughout the year much greater.

The table given above (art. 17, p. 72) shows the tendency, as I have already remarked, of the predominance of sea to equalize the summer and winter temperatures; and this is in accordance with the greater equality of those temperatures in the Falkland Islands and S. Georgia, than in the corresponding northern latitudes. It also appears from the table just referred to, that for the latitudes there given above 40°, the mean temperature for a whole parallel of latitude is higher in the south than for the corresponding parallel in north latitude. Now if this be due to the predominance of sea in the southern,

* This temperature is not very certain, even should the map be exact, since there is no July isothermal given in the southern hemisphere quite so far south as South Georgia.

and of land in the northern hemisphere, it would appear that the mean annual temperature of a *sea* station on the parallel of 50° N. latitude, would not exceed that of a similar sea station in equal S. latitude, unless the temperatures should be materially influenced by local causes. Hence the lower temperature of the Falkland Islands, as compared with that of the corresponding northern parallel, must be due either to local influences, or to too high an estimate of the mean annual temperature in western Europe in the hypothetical case of the absence of the Gulf-stream. I am disposed to attribute it to the latter reason. The temperature of the Falkland Islands may be depressed by a southern continent not very distant from them, and by consequent accumulations of ice; but it would seem that the region of western Europe about the parallel of 50° would, in the absence of the Gulf-stream, be liable to an equal similar influence from the Scandinavian region. I am disposed, therefore, to think that the isothermal lines for this case, represented on the map, ought to meet the coast of western Europe at points rather more southerly, so as to indicate temperatures for each locality about 2° or 3° lower than those now indicated. I might have made this correction on the map, but, as the determination of the positions assigned to these isothermals was entirely independent of any comparison with places in the southern hemisphere, I have thought it better to allow them to remain, as a proof of the approximate accordance of results arrived at by independent considerations. These corrected positions of the isothermals would assign to Snowdon, in the absence of the Gulf-stream, a mean annual temperature of 39° or 40°.

19. In more northern latitudes than that of Snowdon, our foregoing reasoning would lead us to conclude that the mean annual temperature would be increased by the submergence of Europe, but only in a comparatively small degree for insular stations and those situated immediately on the shores of the Atlantic. The temperatures, therefore, of the northern extremity of Scotland and of Iceland, under our present hypothesis, may be taken somewhat greater than those given in the table of art. 13, p. 68, for the case in which the absence of the Gulf-stream was assumed. The temperature of the Alps would probably differ little from that given in the same table. The correction mentioned in the preceding paragraph, if adopted, must, of course, be applied also to these temperatures.

§ II. *On the Height of the Snow-line and Descent of Glaciers below it,* (1.) *at the present time*; (2.) *in the previous hypothetical cases.*

(1.) *On the Height of the Snow-line at the present time.*

20. Knowing the mean annual temperature at any place on the earth's surface, we can calculate for that place the height at which the mean annual temperature of the atmosphere will be that of freezing, provided we know the rate at which the mean temperature decreases, in ascending from the lower into higher regions of the atmosphere. This rate has been determined with sufficient accuracy

for our purpose. It is necessary to make a distinction between those observations which have been made in balloons or on the sides of comparatively steep mountains, and those which have been made on extensive elevated table-lands; the results in the two cases being very different. Of the first class, Humboldt has given us* the results of nine cases, in which the observations were made at different heights, varying from about 5000 to 18,000 feet. The mean of the results gives 191·4 metres, or about 638 feet for 1° Cent., which is equivalent to 355 feet for 1° Fahr. In Gay-Lussac's balloon ascent, the observations gave 193 metres for 1° C., up to the height of about 12,000 feet. At greater heights the decrease of temperature was somewhat more rapid, and was at the rate of 1° for 187 metres for the whole height ascended, which amounted to upwards of 23,000 feet. We may adopt, without risk of material error, 190 metres for 1° C., or 350 feet for 1° F. In some particular cases, however, 320 feet would probably be nearer the truth.

Humboldt has also made some valuable observations, which show the effect of extensive high table-lands in raising the temperature above that which would be given by calculations founded on the result just enunciated. In ascending from one table-land to another, the decrease of temperature is much slower than if we should ascend in a balloon, or up the side of a steep mountain. The following table exhibits the results of Humboldt's observations on four of the highest table-lands on the new continent:—

Place of Observation.	Latitude.	Height.	Mean Temperature.	Increase of Height for 1° C.
	° ′	metres.	°	metres.
Quito	0 13 S.	2907	15·0 C.	244·4
Popayan	2 26 N.	1796	20·6	288·1
San. Fé di Bogota	4 35 N.	2660	16·5	256·0
Mexico	19 26 N.	2277	16·9	249·3

The mean of the numbers in the last column is 258·4 metres. This is equivalent to 478 feet of height for 1° F., instead of 350 feet, as in the former case. The high general temperature of the plains of Tibet (as indicated by the nature of their produce), in proportion to their enormous elevation, is doubtless due to the same cause.

From these results it appears, that we may take a decrease of 1° F. as corresponding to an elevation varying, according to circumstances, from 320 to 500 feet; the smaller number being applicable to small, or, if high, very steep mountains, and the latter to large massive ranges presenting extensive table-lands along their sides. For intermediate cases, intermediate numbers must be adopted.

21. Before the publication of the admirable observations of Humboldt, it was usually assumed, in speculations respecting the line of perpetual snow, that it coincided with that of 32°. Later observations have shown the error of this hypothesis, especially in the higher latitudes. Humboldt has given the following results, deduced

* *Recueils Astronomiques* of his Travels in S. America, vol. i. p. 129.

from his own observations and those of others, respecting the mean annual temperature at the limit of perpetual snow, in different latitudes:—

At Chimborazo, lat. = 1°·28′ S.	Mean temperature of the snow-line	= 32° + 2°·7 = 34°·7 F.
At St. Gothard, lat. = 46° N.	,, ,,	= 32° − 6°·7 = 25°·3
At the Polar Circle	,, ,,	= 32° − 10°·8 = 21°·2

Hence it follows that near the equator the snow-line is nearly 1000 feet lower than that of 32°, while at St. Gothard it is higher than this latter line by about 2000 feet, and at some places on the polar circle by about 3500 feet, according to Humboldt. But in that latitude in the northern hemisphere the height of the snow-line above that of 32° appears to be very variable, as might be expected from the very different conditions under which different regions are situated along the same parallel of latitude. In north-eastern Asia it is probably much greater than 3500 feet, while in Iceland the two lines must nearly coincide.

I am not aware of other similar observations on the temperature of the snow-line, or on the relative heights of that line and of the line of 32°. The height of the snow-line, however, has been ascertained in several other places, and the height of the line of 32° F. may be calculated, and their relative positions determined. Thus for the Pyrenees (lat. = 42° 30′) we have by observation,—

Height of snow-line ..... = 9300 feet.

The mean annual temperature at the level of the sea may be taken at 56°, and therefore the decrease up to the line of 32° will be 24°; and, allowing 320 feet ascent for a decrease of 1° F., we shall have,—

Height of the line of 32° ..... = 7680 feet.

Consequently the height of the snow-line will exceed that of the line of freezing temperature by 1620 feet.

A similar calculation for the Caucasus (lat. 42° 30′), where the height of the snow-line is rather more than 10,000 feet, gives the height of the line of 32° less than 8000 feet, and therefore lower than the former by about 2500 feet. And again, for the Himalaya we have similar results. On the south side of this range, in latitude 32° N., we may take the mean annual temperature, independently of elevation, at 67° F., or 35° above the freezing temperature, and, allowing 400 feet for a decrease of 1° F. in ascending the southern slope of the mountains (art. 20, p. 77), the height of the line of freezing temperature will be 14,000 feet. The height of the snow-line, as given by Captain Strachey, is there 16,000 feet, or 2000 feet higher than the former line. On the north side of the range, allowing 2° F. in the mean annual temperature, independent of elevation, for the difference of latitude as compared with the south side, and 480 feet of ascent for each degree of temperature (art. 20), we have 15,840 feet for the height of the line of 32°. Also we have, on the

same authority as the above, the height of the snow-line 18,500 feet, or upwards of 2600 feet above the former line.

These calculated results as to the difference of heights of the snow-line and that of the temperature of 32° may not of themselves be entitled to much confidence, compared with those deduced from observation; but they show that the data on which the calculations are founded are in accordance with the results of observation in other cases.

22. It appears from the preceding facts, that the height of the snow-line, with reference to the line of 32° F., increases, under similar conditions, as we proceed northward from the equator. For this phænomenon we may assign two principal causes, which it is important for us to notice, in order that we may be able the better to understand the real analogies between actual cases of observation and the hypothetical cases of past geological epochs.

At places near the equator, and especially at great elevations, there is little variation of temperature from one season to another. Let us suppose a case in which the temperature should be entirely equable. The snow-line would be absolutely stationary. Above this line the snow would tend to accumulate by constant deposition, until this tendency should be exactly counteracted by destructive causes, such as the direct action of the sun's rays, evaporation, drifting by the wind, avalanches, &c. The snow-line would be that beneath which these antagonistic causes would cease to be in equilibrium, and its position would manifestly depend *cæteris paribus* on the quantity of snow produced in the atmospheric region directly over that upper portion of the mountain which should be bounded by the snow-line. If the quantity of snow thus formed and falling on the mountain should be very small, the destructive causes would not allow it to remain permanently at so low a level as that of the line of freezing temperature, which might in this case be considerably below the snow-line. On the contrary, if a comparatively large quantity of snow should fall on the mountain, the snow-line might descend to a considerable distance below that of freezing temperature.

But let us now suppose the annual temperature to vary from summer heat to winter cold, the *mean* annual temperature remaining the same. It is manifest that the variable snow-line during the year would in winter be below, and in summer above the permanent snow-line of the previous case, the extent of this oscillation being proportionate to that of the temperature during the year. But the highest or summer position of this variable snow-line is what is properly called *the snow-line*. Thus, while, with a temperature in which the variation from summer to winter should be comparatively small, the snow-line should be below the line of freezing temperature, it might be far above that line if the oscillation of temperature were great, although the *mean* annual temperature should be the same in both cases.

Considering then the position of the snow-line with reference always to the line of 32°, the conditions which produce its lowest positions are those which secure a moist atmosphere with an approximately equable annual temperature. Comparing places in the same

latitude, an insular position will have a lower position of the snow-line than a continental one. In comparing a place near the equator with one in the higher latitudes, there will be much greater humidity in the atmosphere and much less variation in the annual temperature in the former case than in the latter, and both these causes tend to produce a much lower position of the snow-line, with reference to the line of 32°, in the former case than in the latter. These general causes, independently of the action of mere partial causes, are sufficient to explain the general results of observation above given.

23. After the preceding considerations respecting the relative positions of the line of 32° F. and the snow-line, I proceed to examine the distances, measured vertically, to which the principal known glaciers descend below this latter line, which forms the limit of a glacier's superficial increase. Such distance must depend on the depth of the glacier, the rate of its motion, and the activity of the destructive agencies to which it is exposed. It is of course widely different for glaciers of different magnitudes, but for those which are sufficiently large to be considered of the *first order* it varies much less than might perhaps be expected, as appears from the following table, p. 81. The glaciers specified are all of the first order in magnitude, except, perhaps, that of the Maladetta.

It will be observed that the descent of the Aar glacier below the snow-line is considerably less than that of any other equally large glacier enumerated in the opposite table. This I conceive to be due to the very small inclination of the bed of that glacier towards its lower extremity. If we reject this example as anomalous, the mean descent of the remaining nine great glaciers below the snow-line is about 4500 feet.

There are also three glaciers in the Himalayas, from the extremities of which the Pindur, the Gori, and the Ganges issue. The heights of these sources have been incidentally given by observers*, as being respectively 11,946, 11,543, and 13,500 feet. Taking Capt. Strachey's estimate of the height of the snow-line as 16,000 feet in that region, we have 4054, 4457, and 2500 feet for the descents of these glaciers below the snow-line. The two former are in very near accordance with the mean of the cases above given; the last more nearly accords with the smaller descents of the glacier of the Aar, and is probably due to a similar cause.

The glaciers which proceed from more limited spaces for the accumulation of snow and ice descend below the snow-line to distances much shorter than those above given.

(2.) *Height of the Snow-line, and Descent of Glaciers below it in the hypothetical cases of* § I.

The degree of cold requisite to produce glaciers on a mountain might obviously be caused by the elevation of the mountain. I shall,

* See Captain Strachey's Paper "On the Snow-line in the Himálaya," Journ. Asiatic Soc. Bengal, April 1849; and Edinb. New Phil. Journ. vol. xlvii. 1849; and "On the Physical Geography of the Provinces of Kumáon and Garhwál," Journ. R. Geograph. Soc. 1851.

	Latitude.	Height of the Snow-line.	Names.	Height above the Sea.	Height above the Snow-line.	Name of the Glaciers.	Height of the lower end of the Glacier.	Descent below the Snow-line.
		feet.		feet.	feet.		feet.	feet.
Pyrenees....	42° 30′	9300	La Maladetta	11,300	2000	Gl. de la Maladetta	7600	1700
Caucasus....	42 30	10,300	Kasbek	15,000	4700	Desdaroki	6400	3900
The Alps..	45 50	9000	Mass of Mont Blanc	13,300	4300	Gl. des Bois	3700	5300
			Mont Blanc..	16,000	7000	Gl. des Bossons..	3700	5300
						Gl. de la Brenva..	4500	4500
	45 30	8800	Mass of the Grindelwald Mountains..	Mean, 13,300	4500	Gl. de Grindelwald	3500	5300
						Gl. d'Aletsch....	4500	4300
						Gl. de l'Aar	6150	2650
Scandinavian Fjelds....	61 43	5500	Summit of Lodalskaabe..	6800	1300	Gl. of Lodalskaabe	1700	3800
			Plateau of Justedal.....	6000	500	Gl. of Nygaard...	1100	4400
						Gl. of Berset .. .	1500	4000

This Table is extracted from the memoir of M. Durocher, in the *Annales des Mines*, 4 sér. tom. xii. 1847.

in the first place, suppose former glaciers in western Europe to have been due to this cause alone, and determine the general elevation of that region which would be necessary to produce such effects, rejecting the supposition, as altogether improbable, that each individual mountain which exhibits glacial phænomena was locally elevated independently of any corresponding elevation of the surrounding region. I shall then proceed to the hypothetical cases of the previous section.

24. The present mean annual temperature of the Alps may be taken at 55°·5 F. (art. 13, p. 68), or 23°·5 above the freezing temperature. The height of the snow-line is about 9000 feet, and that of the line of 32° F. about 7000 feet, which gives a decrease of 1° F. for about 300 feet. If the surrounding region should be elevated several thousand feet together with the Alps, we may take the decrease of temperature for 1° from the level of the sea for about 400 feet (art. 20, p. 77). This would give the height of the line of 32° above the level of the sea, after the elevation, equal to about 9300 feet; and assuming the height of the snow-line to exceed this, as at present, by 2000 feet, the height of that line would be 11,300 feet. It is probable that the glaciers would not in this case descend quite so far below this line as at present. Suppose them to descend 4300 feet below it; the height of their lower extremities would then be about 7000 feet above the level of the sea. Consequently the glaciers would descend into the level of the Lake of Geneva, provided the elevation of the region placed that lake 7000 feet above the sea, or about 6000 feet above its present level.

Hence, if blocks on the Jura have been transported from the Alps by the agency of ice, the Alps must, according to our present hypothesis, have been at least 6000 feet higher than at present, supposing the surrounding region to some extent to have been elevated at the same time.

The present mean annual temperature of Snowdon is about 49°·5 F., or 17°·5 above the freezing temperature. Assuming the general elevation of western Europe, Snowdon would stand on a wide elevated table-land, and we may take the decrease of temperature at 1° F. for about 450 feet*. This would give the height of the line of 32° equal to rather more than 7800 feet, and, supposing the snow-line 2200 feet higher, we have 10,000 feet for the height of this latter line. Now to produce glaciers of considerable magnitude on Snowdon, its summit must probably rise some 1000 feet above the snow-line, or to the height of 11,000 feet. Hence the whole region must be elevated between 7000 and 8000 feet above its present level. The glaciers might then be expected to descend to the table-land at the foot of the Snowdonian mountains, *i. e.* about 2000 feet below the snow-line. Further descent to any extent would be prevented by the comparatively horizontal surface of the immediate foot of the mountains.

In higher latitudes the required elevation would be smaller; but, speaking generally, in order that glaciers should exist on our present

* I take this number greater than for the Alps, because the elevation of the surrounding region would in this case form a higher table-land than that immediately around the Alps.

mountains of sufficient magnitude to descend down to their present bases, in consequence of a general elevation of western Europe, it would be necessary that that region should be raised into an elevated range from the polar circle to the south of the Alps, rising in some parts to the height of 10,000 or 12,000 feet.

25. I shall now take the case in which the old and new continents are supposed to be united by the conversion of the basin of the Atlantic into land. We should have, according to the estimate above given (art. 15, p. 70), the mean annual temperature of the Alps about 44°·5 F., or 11° lower than at the present time. The position of the line 32° F. would therefore be lowered by about 3500 feet, but the distance of the snow-line above it would be much increased by both the causes which appear chiefly to influence that distance. The oscillation of temperature from January to July would be 61° F. instead of 34° as at present, and the quantity of snow falling during the year would doubtless be much diminished by the entire absence of sea in the surrounding region. It would seem probable that the position of the snow-line would be as much raised by these causes, as it would be lowered by the diminution of temperature. Moreover, it is probable, that the glaciers would not descend so far below the snow-line as at present, on account of the diminution of their mass, arising from the diminished quantity of snow. I conceive it probable, therefore, that the Alpine glaciers would not descend, in the case now contemplated, to points less elevated than at present above the level of the sea. In such case it would be necessary to give to the Alpine region about the same additional elevation as in the former case (art. 24) in order that the glaciers should descend to the Lake of Geneva.

The mean annual temperature of Snowdon would be nearly 30° F., and the isothermal of the mean annual temperature of 32° would pass through the mountains of the south-west of Ireland which present many indications of former glaciers. Along this isothermal, the line of 32° F. would coincide with the surface of the earth, and the height of the snow-line above it would be identical with the absolute height of that line, which would therefore be about 2500 feet, if the distance between these two lines should be the same as at present. For the reasons assigned, however, in the preceding paragraph, this distance would undoubtedly be much greater than at present. The oscillation from winter to summer temperature would amount to no less than 73° 5′ F. (art. 15), whereas it is at present only 23°. The present distance, therefore, between the two lines in question being taken at about 2500 feet, it is probable, I think, that in the case now considered, it would not be less than two or three times that quantity. And this conclusion appears to be in accordance with the knowledge we possess of the Altai mountains in the north-east of Asia. Those mountains rise to the height of 9000 or 10,000 feet, and the mean annual temperature is under 32° F.; and yet, as I am assured by that distinguished traveller M. de Tchihatcheff, there are no glaciers upon them of any magnitude, a sufficient proof that the snow-line cannot in all probability be lower than the above estimate.

In proceeding further to the north, the snow-line would probably

meet the level of the sea about the latitude of the northern part of Scotland. In all higher latitudes the surface of the earth would be covered with perpetual snow.

It follows, then, that if the Atlantic were converted into dry land, it would still be necessary, in order to obtain glaciers to the extent required by observed phænomena, that the western part of Europe should be elevated into a range extending nearly from the 40th to the 60th parallel of latitude, and higher than the present surface by some 4000 or 5000 feet.

26. I now proceed to that which I consider by far the most important of our hypothetical cases,—that in which we assume the absence of the Gulf-stream and the submergence of a large portion of northern and central Europe beneath the ocean. There is no difficulty in this case in accounting for the existence of glaciers in the northern parts of Scotland and in more northern latitudes; but it is necessary to consider carefully how far the conditions of their existence in the more southern latitudes in which traces of glacial phænomena are observed, could be fulfilled. I will first consider the Snowdonian region.

Let us suppose Snowdon and the surrounding country lowered 500 feet below its present level. If the whole of Europe were depressed to the same amount, a large portion of it would be submerged beneath the ocean; but we are at liberty to suppose any part of it depressed to a greater amount, if necessary to produce the more complete submergence here assumed. I have estimated the most probable mean annual temperature of Snowdon at 39° or 40° F., in the absence of the Gulf-stream (art. 13, p. 68) and of any cold current from the north; and I have also shown that it would be little altered by the submergence of Europe beneath the sea (art. 18, p. 75). This would give the height of the line of 32° F. equal to at least 2200 feet, or about 800 feet below the summit of Snowdon in its depressed position. In estimating the position of the snow-line with reference to the line of 32° F., it must be recollected that the region about Snowdon would form a group of small islands in the midst of an extensive ocean, and would so far be under conditions favourable for producing a moist climate and a low position of the snow-line relatively to the line of 32° F. I have already (art. 18) referred to Iceland and the island of S. Georgia as furnishing cases similar in conditions to this hypothetical case of Snowdon. Their insular positions and mean annual temperatures are nearly the same as in that case. The difference of summer and winter temperature, however, would be greater for Snowdon than for either of the other cases, being about 14° for S. Georgia, 20° for Iceland, and between 30° and 40° for Snowdon. These considerations would lead us to conclude that the height of the snow-line, with reference to the line of 32° F., would be somewhat higher on Snowdon than in the other two cases. The height of Snæfell Jokul, on the north-west coast of Iceland, is, according to Mackenzie, 4558 feet, and that of the snow-line upon it 2734 feet, as measured by Sir J. T. Stanley. The mean annual temperature there is about 38°, and consequently the height of the line of 32° must be about 2000

feet, upwards of 700 feet below the snow-line. On the south coast of Iceland the mean annual temperature is about 40°, and the height of the line of 32°, consequently, less than 3000 feet. The height of Eyafialla Jokul is about 5500 feet, and the height of the snow-line is probably much the same as at Snæfell. The glaciers there are stated to descend nearly to the level of the sea.

I have estimated the mean annual temperature of the island of S. Georgia at 38°. Consequently, the line of 32° will be at about the elevation of 2000 feet. It is very desirable that more accurate observations should be made on the height of the snow-line in that island than, I believe, have hitherto been obtained. The vague assertion that the snow-line there descends to the level of the ocean, has probably arisen from confounding that line with the level to which the glaciers descend. All we seem to know is, that glaciers descend to the margin of the sea; but before we can reason conclusively on this, as a case analogous to that of Snowdon or of other mountains in our own islands, it is necessary to know more than I have at present been able to ascertain, respecting the height and configuration of the mountains from which the glaciers descend. Mr. Darwin in his Journal quotes Cook's description of the island, but it contains no accurate information on the points in question, although it would lead to the inference that the snow-line must be considerably below the line of 32° F.

It would seem very possible then, that the snow-line on Snowdon in the present hypothetical case might not be higher than the line of 32° F., the height of which is above estimated at 2200 feet. Glaciers might thus descend from a snow-line little more than 2000 feet high to the level of the sea.

27. If, in addition to the hypothesis of the absence of the Gulf-stream, we adopt that of a cold current from the north, sweeping over the submerged portions of northern and western Europe, we shall have an additional cause which might probably lower the mean annual temperature of Snowdon and the neighbouring region by 3° or 4° below that above assumed. Such a current would also tend to equalize the summer and winter temperatures, since its effect would there be principally or entirely produced on the summer temperature, which might thus possibly be lowered 6° or 8°. The snow-line would thus be brought at least 1000 or 1200 feet lower than above supposed. This would be sufficient to account for glaciers descending to the sea, not only on Snowdon, but also on the lower mountains of the west of Ireland.

28. Conclusions, but somewhat vague, have been drawn respecting the former possible existence of glaciers in western Europe, from the actual existence of glaciers descending to nearly the sea-level in South America, in comparatively low latitudes. But in this comparison the relative heights of the mountains in the two regions has been frequently, I think, overlooked. In the case we have been discussing, the mean annual temperatures in corresponding latitudes in the two hemispheres would be almost exactly the same, and probably the quantity of moisture in the atmosphere and the quantity of snow

in similar positions might be much the same; but the greater extent of land which must have existed in the northern hemisphere, as compared with the southern, in the more recent geological periods, must have rendered the summer temperature greater in the northern than in the southern hemisphere, and consequently the snow-line and, *cæteris paribus*, the lower extremities of the glaciers somewhat higher in the former than the latter region. The great distinction, however, between the western coast of South America and that of Europe consists in the great difference in the heights of their mountains. A glacier is described by Mr. Darwin* as descending to the sea-level in the Gulf of Penas, on the west coast of South America, in latitude 46° 40′. According to Dove's map, we have for that place—

July temperature.....	40° F.
January temperature	50
Mean annual temperature	45

Hence the height of the line of 32° must be about 4500 feet. The difference between the January and July temperatures is only 10°, the latter being considerably reduced by the cold current passing round Cape Horn. This, with the proximity of the Pacific, is highly favourable to a low position of the snow-line. It may probably lie near the line of 32°, or even considerably lower, in which case the glacier must descend between 4000 and 5000 feet below it. This coincides with the distances to which almost all glaciers of the first order descend below the snow-line (art. 23, p. 81) and presents nothing anomalous. It is described as a very large glacier, descending from a lofty mountain, which rises, undoubtedly, many thousand feet above the snow-line. It is in this respect that the analogy between the glaciers of South America and those which may have formerly existed on such mountains as those of the British Islands entirely fails. With the same climatal conditions, we might have glaciers descending to the sea-level in the one case, without a trace of glaciers in the other.

29. I shall now discuss the case of the Alps. Adopting the hypothesis of a current from the north, it is manifest that such a current would, as already remarked, tend much to equalize the temperature from the latitude of Snowdon to that of the Alps in the present region of western Europe, precisely as the Gulf-stream now equalizes in so remarkable a degree the temperatures of different latitudes in a considerable portion of its course in the northern ocean. If we assume its effect on the mean annual temperature of the Alpine region to be 8° or 9°, instead of 3° or 4°, as in the Snowdonian region, we shall probably not over-estimate its influence. The mean annual temperature would be thus reduced to about 45°. The height of the line of 32° would then be about 5000 feet. The difference of summer and winter temperatures would be considerably less than at present, and the position would approximate much nearer to the character of an insular one. Both these circumstances would be

* Darwin's Journal, p. 284.

favourable to a lower position of the snow-line with reference to the line of 32°, than at present, and the latter also to the production of snow. Under such circumstances glaciers might descend to the sea-level, where the configuration of the mountains should be sufficiently favourable to their descent, and supposing the sea to stand at such a relative height as to reach the bases of the mountains. That this was the case, I have little doubt; for with the conviction that an enormous erratic block like the *pierre à bot*, above Neufchatel, must have been transported across the valley of Switzerland by floating ice, I think it most probable that the whole Alpine region was, at the glacial period, 2000 or 3000 feet at least lower than its present level; so that the sea might not only extend to the base of the Alpine range, but might also penetrate into many of its lower valleys.

Thus it appears from this investigation, that the same conditions which would produce glaciers on our Welsh and Irish mountains, descending to the level of the sea from a snow-line from 1000 to 1500 feet above that level, might also produce similar phænomena in the Alps with a snow-line 5000 or 6000 feet above the sea. In more northerly regions there would, of course, be no difficulty in accounting for the existence of similar glaciers.

§ III. *Discussion of the Relative Claims of the preceding Hypotheses.*

I have already stated that I considered the hypotheses discussed in the first part of this memoir entirely insufficient to account for any sensible changes of terrestrial temperature in the later geological periods, as they obviously are to render account for a change from a lower to a higher temperature. In the earlier periods of the earth's history, supposing our globe to have been originally, as there are many reasons for believing it to have been, in a state of fusion, its superficial temperature must have been greatly affected by its internal heat long after the solidification of its surface had commenced. Undoubtedly this cause may be appealed to as sufficient for the production of almost any amount of terrestrial temperature; but, if the temperatures thus to be accounted for be many degrees above the existing temperatures, we can only account for them by this theory with reference to periods of very remote geological antiquity (art. 6, p. 59). I have also shown that any sensible effects of a difference of intensity in stellar radiation can only be referred to similarly remote epochs, and even for those periods the theory founded upon this notion appears to me but vague and unsatisfactory.

Another theory of the changes of terrestrial temperature has been founded on the notion of a variation in the intensity of solar radiation. This cause, once admitted, might undoubtedly be deemed adequate to account for all the changes in question, nor does there appear to be any well-defined *à-priori* objection to it. No theory, however, can be satisfactory which presents itself as a mere hypothesis framed to account for a single and limited class of facts, and unsupported by the testimony of any other class of allied, but independent phæ-

nomena. The reception of such a theory must always be accompanied with great reserve, and must depend less on its own positive claims, than on an equal or greater want of such claims on the part of rival theories.

The theory which attributes the changes of terrestrial temperature to a varying configuration of land and sea is scarcely less indefinite than the others in its direct application to account for the difference of temperature between the present and the very remote geological epochs, on account of our ignorance of the disposition of sea and land in any but the most recent geological times. In the more remote periods, more than one of the causes here specified may have had their influence; but in accounting for the more recent changes of temperature, the last-mentioned theory appears to me to have by far the greatest claim to our attention. I have endeavoured in the preceding Sections of this second Part of my memoir to trace the consequences of certain hypothetical configurations of the earth's surface, and to explain the conditions under which a degree of cold might exist adequate to produce the phænomena of the Glacial Epoch. I propose in this concluding Section to offer a few leading observations on the relative claims of these different hypotheses to our acceptance.

30. The most obvious mode of producing a great degree of cold is by local elevation. If we attribute the former presumed cold of western Europe to this cause alone, it would be necessary, as I have shown (art. 24, p. 82), to elevate the whole region into a vast mountain-range, attaining in some parts the height of 10,000 feet or upwards. But all geological experience assures us that no such mountain-range exists without numerous dislocations and other phænomena of elevation having determinate relations to the elevated tract. Of such characteristic phænomena not the slightest traces have been recognized. If it be urged that the elevation might be more local than here supposed, I would reply that such an hypothesis would rather strengthen than weaken the objection; for the more local the elevation, the more certainly, I think, would it be accompanied with dislocations which could not escape detection. I should reject without hesitation any theory founded on the hypothesis of an elevation during the glacial period, at all approximating to that which would be necessary to produce the required degree of cold.

31. Again, a great degree of cold might be produced by the conversion of a sufficient portion of the Atlantic into dry land. But this would also require an elevation of western Europe, probably of several thousand feet (art. 25). Now if the cold of the glacial epoch were thus produced, this enormous area of the Atlantic must have been uplifted from its former level immediately previous to that epoch, and must since have again subsided. Considering the probable depth of the Atlantic Ocean, this movement must indeed have been enormous, and yet, although occurring at the most recent geological period, not a trace of it is observable either on the European or American side of the Atlantic. Under any circumstances, a theory founded on such an hypothesis would, I think, be most unsatisfactory, and cannot be

accepted in opposition to any other theory which may be free from objections of so grave a character.

We may also observe, that any theory of the production of cold solely by the *elevation* of the regions presenting glacial phænomena would be insufficient to account for many of these phænomena. It would be necessary that such a theory should embrace also the *depression* of such regions beneath the level of the sea, either before or after their elevation, for some of the phænomena in question may be referred to floating ice and currents of water with quite as much certainty as others can be to the action of glaciers.

32. Again, I have shown that the requisite degree of cold for the production of glaciers might arise from the diversion of the Gulf-stream into some other channel, the submergence of a great portion of the existing European continent, and a cold current from the north. This diversion of the Gulf-stream might be produced by the elevation of a portion of the bed of the Atlantic so as to form connecting land between the most western part of Africa and the most eastern portion of South America. But this would require an enormous movement, of which, I believe, not the slightest geological indication has been recognized, and the hypothesis is therefore liable to the same objection as that which may be made against the supposition of the more northern portion of the Atlantic having been elevated into dry land during the glacial period. But there is another mode in which the diversion of this great current may, as it appears to me, have been effected, and to which I would especially direct the attention of geologists.

33. On the west of the continent of North America, a continuous and lofty range of mountains, the Rocky Mountains, extends from Mexico to the Arctic Sea. Another, but far less lofty chain, the Alleghanies, runs parallel to the eastern coast from near the Gulf of Mexico to the St. Lawrence. The great valley of the Mississippi and its tributaries, extending over some 30° of longitude, occupies the southern portion of the space between these two mountain-chains, being bounded on the south by the Gulf of Mexico, into which the Mississippi discharges its waters. In proceeding from the mouth to the source of this great river, we ascend about 1500 or 1600 feet*. Proceeding northward from its source, we descend into the great valley extending from the Gulf of St. Lawrence, on the eastern coast, along the great chain of North American lakes, to the mouth of the Mackenzie River, which discharges itself into the Arctic Sea. Thus a depression of 2000 feet would convert the valley of the Mississippi into a great arm of the sea, of which the present Gulf of Mexico would form the southern extremity, and which would communicate at its northern extremity with the waters occupying the submerged district above-described as the great valley now occupied by the chain of lakes. A direct communication would thus be produced between the Gulf of Mexico and the Arctic Sea along the eastern base of the Rocky Mountains.

* See Sir John Richardson's paper "On some points of the Physical Geology of North America," Quart. Journ. Geol. Soc. 1851, vol. vii. p. 212.

The Gulf-stream, flowing through the Straits of Bahama, and afterwards, in its north-eastern direction, towards the North Sea and the coasts of Europe, is a current reflected from the shores of the Gulf of Mexico in consequence of the impossibility of its continuing the north-western course by which it reaches the Gulf. But in the case now supposed, a direct opening would be made exactly in the direction which the current would continue to follow if uninterrupted. Its continuance to the Arctic Sea, and its non-reflexion through the Straits of Bahama, would be the obvious consequences of the depression of the continent of North America. It would thus lose all sensible influence on the coasts of western Europe, but it would necessarily increase the temperature along its new course, and especially in the cold region of north-western America towards the present shores of the Arctic Sea. The north-eastern portion of the present continent would probably be much less affected by it.

34. It is probable that every great oceanic current must have its counter-current. Now, if the mass of water constituting the Gulf-stream were poured, as here supposed, directly into the Arctic Ocean, the only course, which any great counter-current from that ocean could follow, would seem to be through the North Sea intervening between the coasts of Norway and Greenland, and across the submerged portion of northern Europe. There would in fact be no other considerable opening from the north; for even, if we suppose the low lands of northern Asia to be submerged, the mountain-ranges of that region would still offer an insuperable bar to any egress, except in the direction above indicated, for the waters of the Arctic Ocean. The opening through Behring's Straits would probably not be worthy of notice. These considerations appear to me to increase considerably the probability that this diverted course of the Gulf-stream would be attended by a cold current over the region now occupied by the continent of northern and western Europe.

35. The theory which I have here proposed respecting the diversion of the Gulf-stream, is not to be regarded as resting on an hypothesis framed simply to enable us to account for a particular class of phænomena. I regard it, on the contrary, as resting on a necessary inference from the submergence of the North American continent; for, I repeat, if that continent were submerged to the depth implied, as I believe by the most conclusive geological evidence, the course of the Gulf-stream could be no other than that which I have assigned to it. It is necessary, according to this view of the subject, to suppose this to have been the course of the current during the period of greatest cold in Europe, but it is by no means necessary to extend the supposition to the whole period of submergence of a great portion of the American continent. Many of the glacial phænomena of that region might be produced during its partial submergence, before the depression of the land was sufficient to admit the current to the Arctic Sea, or after its course had been again impeded, or altogether arrested, by the partial subsequent elevation of that continent. During the uninterrupted course of the current to the north, it would doubtlessly, as I have above remarked, increase, and probably very

much increase, the temperature of the region corresponding to the present shores of the Arctic Sea; for nearly the whole of that mass of warm water, which now elevates so remarkably the temperature of the northern Atlantic up to the North Sea, would then proceed to discharge itself into the Arctic Sea between the Rocky Mountains and Hudson's Bay, by a course shorter, more direct, and probably therefore more rapid, than that by which it now reaches the coast of Iceland. I should consider it most probable that it would produce a temperature in the region along the north-eastern flank of the Rocky Mountains, and extending to the present northern shores of the American continent, higher than that of Iceland, and more nearly resembling that of some parts of our own island.

After having arrived at this conclusion, I was naturally anxious to learn whether any distinct indications had been observed of this climatal condition of the region in question, and recollecting to have heard my friend Prof. E. Forbes make incidental mention of the discovery in high northern latitudes of vegetable remains indicative of a temperature considerably higher than the existing temperature, I wrote to him, stating my own conclusions, to ascertain the precise locality in which these remains had been found, and the period to which they belonged. A few days ago I received his reply, stating that these plants might belong to the pleistocene period, and that the locality in which they had been found was precisely that above spoken of, along the flanks of the Rocky Mountains and between them and Hudson's Bay, as the region of which the temperature would probably be so much affected by the warm current from the Gulf of Mexico. I cannot but regard these remains as strongly confirmative of the view which I have now ventured to propound.

But how, it may be asked, could such a warm current be consistent with the glacial phænomena of the North American continent? I have already intimated the reply to this question. The exact period of these phænomena might be either anterior or posterior to that during which the Gulf-stream made its way to the Arctic Sea. Suppose the superficial configuration of that continent previous to its submergence to have been similar to its present configuration. A gradual subsidence might convert the northern portion of the continent into an arctic sea long before a free north-western course would be opened for the Gulf-stream. With the exact similarity of the former and present configuration, this extended arctic sea would be bounded towards the south by the higher land which now constitutes the watershed between the great northern valley of the chain of lakes and that of the Mississippi; but if the former and present configurations of the land were only approximately and not accurately similar, or if the submergence were more rapid in the north than in the south, the boundary of the extended Arctic Ocean might pass further to the south, and comprise, for instance, the northern part of the valley of the Mississippi, before the Gulf of Mexico extended its waters much to the north of its present boundary. In like manner, similar conditions might obtain during the subsequent emergence of the land. Minor hypotheses of this kind, entirely subsidiary to

the general hypothesis with which they are associated, must be considered as always admissible, and can only be tested by observed phænomena. One remark, however, should here be made. The periods of greatest cold in America and western Europe respectively could not, according to this theory, be *exactly* synchronous. Assuming, as we have done, the Gulf-stream to have existed during the supposed changes of level of the North American and European continents, it must have exerted its warming influence in the more northern latitudes, either as a direct current along the flanks of the Rocky Mountains, or as a reflected one on the western coasts of Europe. The cold due to the absence of its influence in both these regions could not be strictly simultaneous, although belonging to the same geological period. This is an essential conclusion of the theory. I know not whether there are any geological facts which tend either to favour or oppose it.

36. It only remains for me to say a few words respecting the hypothesis made in the early part of this memoir (art. 14, p. 68) of the continuity of land from the north of Scotland to the coast of Greenland. I have stated my opinion that the mean temperature along such a northern shore of the Atlantic might be increased 4° or 5° F., and that the winter temperature would probably be much the same on the coast of Iceland as in the latitude of central France. The climatal change might possibly be still greater than here estimated.

M. D'Orbigny has observed about a dozen species of sublittoral molluscs in the West Indies, which he regards as identical with species now inhabiting the western shores of the old continent in corresponding latitudes. Now admitting the theory of the dispersion of specific forms from single centres, this identity of species would imply some connection between these localities on opposite sides of the Atlantic, either by dry land or a shallow sea-bottom. I have already stated (art. 32) the grave difficulty which besets the hypothesis of a barrier of land across the Atlantic, and a similar difficulty must attach to the hypothesis of a shallow sea-bottom. The continuity of the northern shores of the Atlantic warmed by the Gulf-stream may possibly enable us to avoid the far more difficult hypothesis just mentioned. I merely suggest this hypothesis, however, for the consideration of those who may adopt the above opinion of M. D'Orbigny, and draw from it the inference of a former connection between the localities in which the identical species are found.

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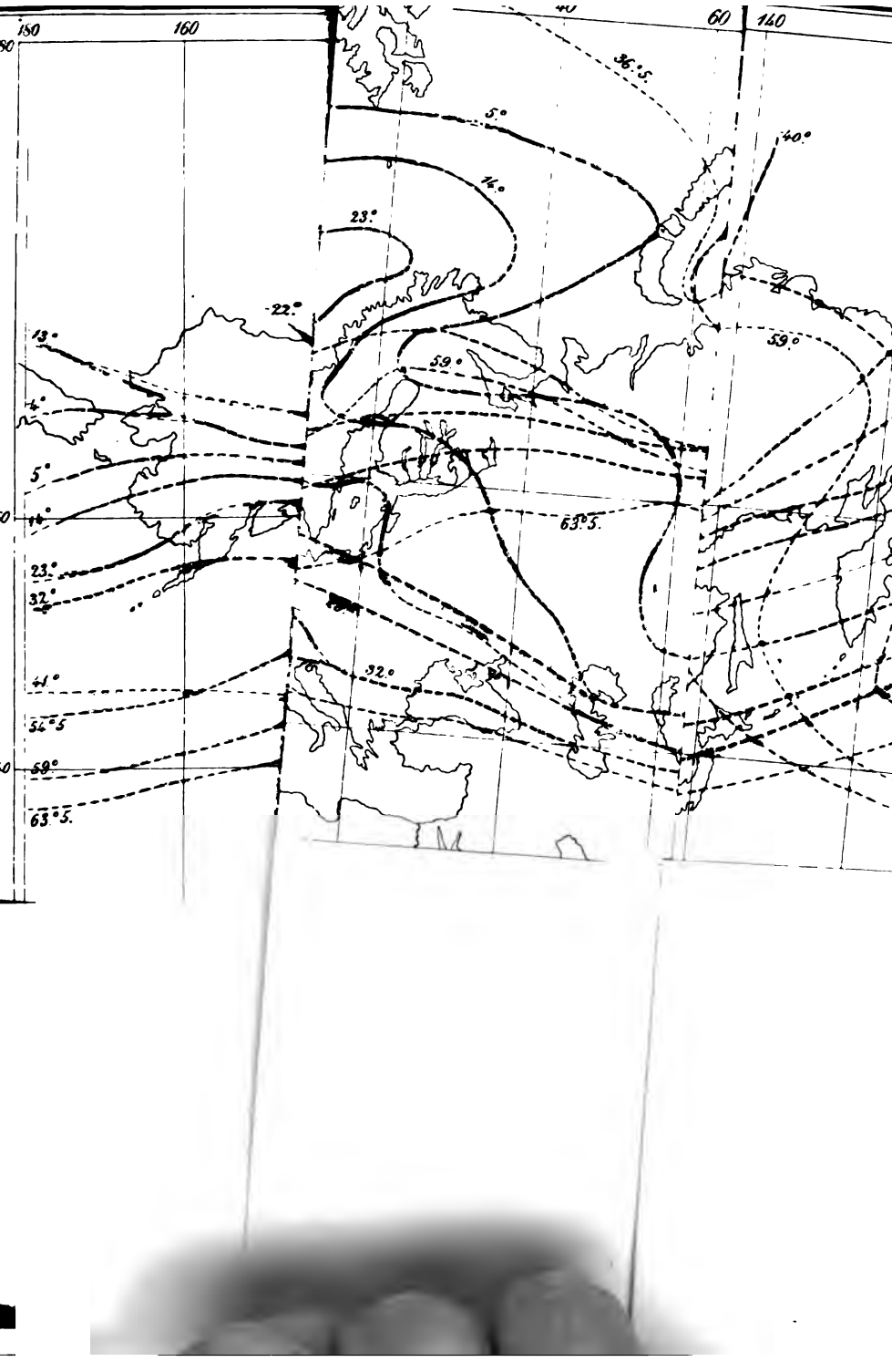
3. Notice *of the* Discovery *of* Reptilian Foot-tracks *and* Remains *in the* Old Red Sandstone *of* Morayshire. By Capt. L. Brickenden, F.G.S. *With a* Description *of the* Telerpeton Elginense, *and* Observations *on* Supposed Fossil Ova *of* Batrachians *in the* Lower Devonian Strata *of* Forfarshire. By G. A. Mantell, LL.D., F.R.S., G.S. &c.

[The reading of this Paper in full was deferred until the next Evening Meeting.]


180
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DONATIONS

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I. TRANSACTIONS AND JOURNALS.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

JANUARY 7, 1852.

Joseph G. W. Watson, Ph. D., the Rev. Charles Pritchard, M.A., John Phear, Esq., James Hepburn, Esq., and T. Rupert Jones, Esq. were elected Fellows.

The following communications were read:—

1. *Notice of the Discovery of* REPTILIAN FOOT-TRACKS *and* REMAINS *in the* OLD RED *or* DEVONIAN STRATA *of* MORAY. By Capt. LAMBART BRICKENDEN, F.G.S. *With a* DESCRIPTION *of the* TELERPETON ELGINENSE, *and* OBSERVATIONS *on supposed* FOSSIL OVA *of* BATRACHIANS *in the* LOWER DEVONIAN STRATA *of* FORFARSHIRE. By GIDEON ALGERNON MANTELL, Esq., LL.D., F.R.S., G.S., Pres. West London Medical Society.

[The Reading of these Papers was deferred from December 17.]

I BEG to submit to the Geological Society a brief notice of a discovery of considerable interest, which I made during the last year, but was prevented from communicating before the close of the last Session; a delay which I do not now regret, since a recent fact has come to

light which invests with additional importance that which it was my object to lay before the Society.

In 1850 I discovered in the quarry of Old Red at Cummingston near Elgin, a slab of sandstone bearing a beautiful and distinct series of quadrupedal foot-prints, of which a representation, one-sixth the size of the original, is given in the annexed sketch (Pl. III.).

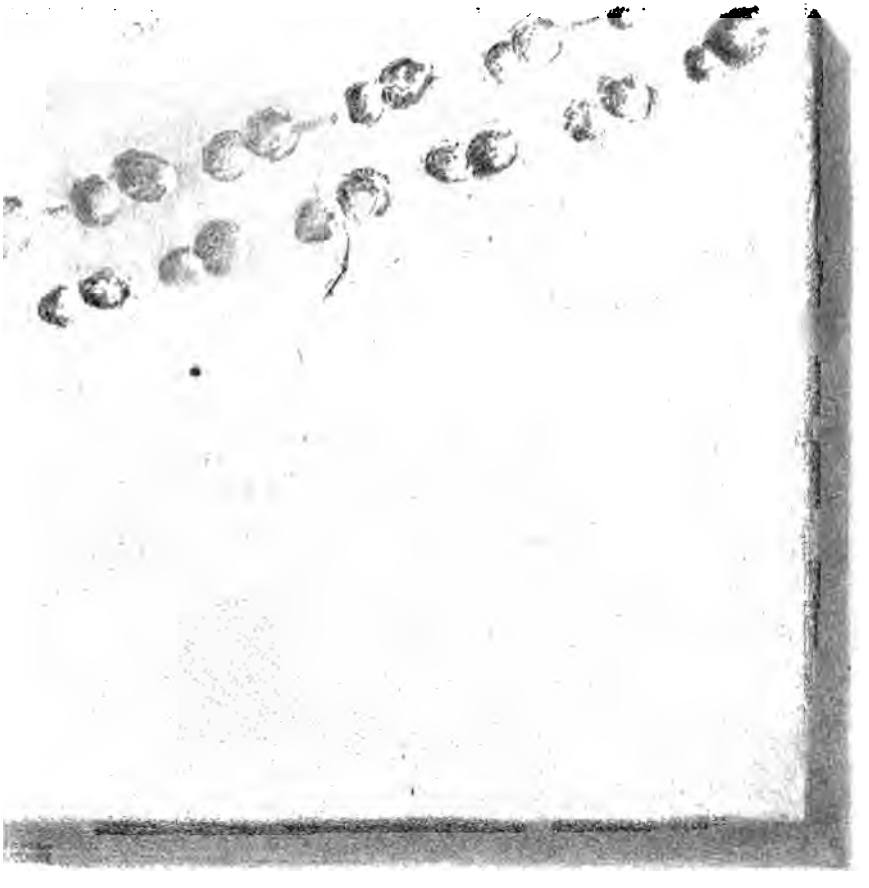
The slab exhibits on the surface, in a very striking manner, thirty-four foot-prints of a quadruped, traced in an uninterrupted succession across the stone. The impressions of the right feet alternate with those of the left, from which they are separated laterally by an interval of three inches, the length of each stride or pace being about four inches. The imprints of the fore and those of the hind feet are nearly in contact, and bear a precisely similar relation throughout: the size of the foot-marks of the former in proportion to the latter is as three to four; the hinder being about one inch in diameter. The imprints are slight cavities, and are all characterized by the same rounded and blunt appearance, apparently indicating that the articulations of the feet were closely connected, although, from the crystalline and arenaceous surface of the stone, the form and number of the joints of the toes cannot be positively determined. A slight trailing mark is observable between some of the foot-marks. In some of the marks it appears that the foot, in pressing on the originally yielding sand, had slightly raised the surface at the heel, but this is scarcely perceptible in the drawing. The strata of yellow sandstone, from which the above slab was removed, prevail in great thickness on the sea-coast of Moray, between the villages of Covesea and Burghead, and are regarded as belonging to the upper division of the Devonian Series of Scotland; and this opinion is based on the fact of finding the yellow sandstone in apparently consecutive order of position to, or closely connected with, neighbouring rocks which are unquestionably Old Red.

It unfortunately happens that we have but few organic remains to assist in determining the relation of these strata; for with the exception of the relics of that remarkable Devonian fish, the *Stagonolepis Robertsoni*, of Agassiz, not a fossil of any kind had been found in the Covesea rocks, until the discovery of the foot-tracks in question.

Within the course of the last month, however, a neighbouring hill on the margin of Loch Spynie, hitherto barren of organic remains, but which, like that of Covesea, is held to be Devonian, has yielded from the bottom of its deep quarry a beautiful specimen of a Reptile, which, although its entire length could not have exceeded seven or eight inches, exhibits the vertebral column, ribs, the extremities, and the skull in a compressed state, with some small conical teeth, having a smooth enamelled surface.

This peculiarly interesting relic came into possession of Patrick Duff, Esq., of Elgin, who has liberally permitted me to transmit it to London, for the examination of my friend Dr. Mantell, by whom the accompanying description has been drawn up.

I would here mention that at the time of my finding the foot-tracks at Cummingston, a strict investigation took place as to whether



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EAR ELGIN.

the sandstone strata from which the slab was obtained are unquestionably referable to the Devonian formation, to which they had always been considered to belong; the occurrence of foot-prints, apparently of Chelonians, in rocks in which no vestiges of the class *Reptilia* had ever been observed in any part of the world, having led some persons to doubt whether they might not be connected with the Permian Series. The discovery of the Reptile at Spynie, by Mr. Patrick Duff, dispels, however, all doubts on this point, for the sandstones of Cummingston and Spynie are identical, and at Spynie are overlaid by the cherty limestone peculiar to the upper division of the Devonian in this district.

Figs. 1 and 2.—*Sections showing the Relation of the Sandstone and Limestone Rocks in the neighbourhood of Elgin.*

Fig. 1.

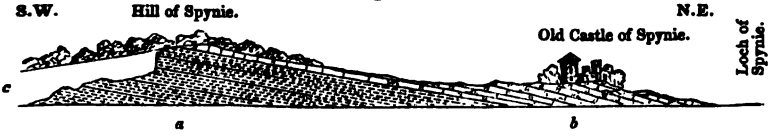
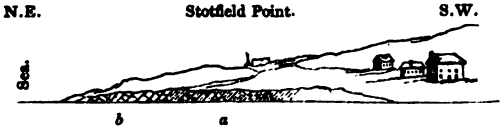


Fig. 2.



a, *a*. Sandstone } Devonian.
b, *b*. Limestone }

c. The sandstone quarry from which the fossil reptile was obtained.

The yellow sandstone of Stotfield is a continuation of that of Covesea, from which latter the Foot-prints were obtained.

The relative position of the strata in the two localities above referred to is shown in the accompanying figs. 1 & 2. The quarry from which the reptile was obtained is situated on the Hill of Spynie; the locality whence I extracted the slab with foot-prints is to the north-west, and separated from the former beds by Loch Spynie.

I am reminded, by the accomplished editor of 'The Witness,' Mr. Hugh Miller, "that the Dipterian family, in which M. Agassiz places that unique ichthyolite the *Stagonolepis Robertsoni*, is emphatically an Old Red Sandstone family, represented in the coal-measures only by a *Diplopterus*, and in the Permian series it is without a representative at all."

By the discovery, therefore, of the foot-prints at Cummingston, and of the Reptilian skeleton at Spynie, Morayshire, we have now obtained indisputable evidence in our own country (I believe for the first time) that the class *Reptilia* existed at that very remote period

of the world's physical history, which is defined by the deposition of the strata, termed by geologists the Old Red, or Devonian formation.

Description *of the* Telerpeton Elginense, *a* Fossil Reptile *recently discovered in the* Old Red Sandstone *of* Moray; *with* Observations *on supposed* Fossil Ova *of* Batrachians *in the* Lower Devonian Strata *of* Forfarshire. By Gideon Algernon Mantell, Esq., LL.D., F.R.S., G.S., Honorary Fellow of the Royal College of Surgeons of England, President of the West London Medical Society, &c.

The highly interesting fossils from the Devonian rocks of Morayshire, which Mr. Patrick Duff of Elgin has with great courtesy allowed my friend Captain Brickenden to transmit to me, with a request that I would examine and describe them, and lay the results before the Geological Society of London, consist of the remains and impressions of nearly the entire skeleton of a lacertian reptile, 4½ inches in length, in a block of crystalline sandstone broken into three pieces.

On the largest fragment, Pl. IV. 9, the spinal column with the ribs, from near the occiput to the sacrum, is distinctly shown; the pelvis is but obscurely indicated; the caudal vertebræ with their apophyses, comprising apparently two-thirds of the entire tail, are manifest. There are no traces of the bones of the pectoral arch, nor of those of the feet. Of the left anterior extremity, impressions of the distal half of the humerus, and of the proximal portions of the radius and ulna are the only vestiges; the right arm is indicated solely by a hollow left by the humerus. The forms of the bones of the hinder limbs are demonstrated by the deep imprints of the femora and tibiæ, and less distinct traces of the fibulæ.

The piece of sandstone, Pl. IV. 8, that has been broken from the upper part of the block, Pl. IV. 9, nearly parallel with the plane of the spine, displays the corresponding impressions of the vertebral column and ribs, pelvis, bones of the hinder limbs, and tail.

The third portion of stone, Pl. IV. 4*, 4, has been detached from the anterior part of Pl. IV. 9; it contains the cranium in a very mutilated state, and in a great measure concealed by the investing matrix. The removal of the surrounding sandstone would probably disclose characters that might assist in determining the natural affinities of the original animal, but as this unique and most important relic was entrusted to me for description only, I have not ventured to attempt its more complete development; in fact, the extreme fragility of the specimen would render such an operation very hazardous.

With the exception of the imbedded skull, scarcely any vestige of the osseous substance remains; impressions, more or less distinct, of the spinal column, pelvis, and extremities, and replacements or casts of a considerable number of the vertebræ by the investing rock are the only indications of the form and structure of the Devonian reptile which the researches of Mr. Duff have brought to light.

In the largest block (Pl. IV. 9) the dorsal aspect, or upper part, of the skeleton is exposed. The vertebral column and ribs are almost in a normal position; the cranium is somewhat displaced, and lies on

one side; the extremities are partially extended, and the thigh-bones directed forwards; the tail is curved towards the right.

At the first glance the fossil presents so striking a resemblance to the skeleton of a small lizard, that upon a hasty inspection, I had no doubt that it belonged to a lacertian reptile, and anticipated but little difficulty in determining the form and relations of the original: but a careful examination disclosed anatomical characters, which, if I have rightly interpreted, indicate an approach to the batrachian type: the results of a rigid investigation and comparison of every recognizable part of the skeleton are embodied in the following description.

Cranium.—From the outline of the mutilated skull, which can be traced but imperfectly, the form of the head appears to have been oblong, with a gently rounded muzzle (Pl. IV. 3, 4). The remains of the vomerine and palatine bones are seen between the imprints left by the lower jaw, but are too much crushed to afford any satisfactory information as to the original form and structure of this part of the cranium. The impressions of the distal or articular portion of each ramus of the lower jaw are faintly shown, as sketched in Pl. IV. 3, and 4, *a*, *a*; but I have searched in vain for indications of the divisions of the several parts that enter into the composition of the inferior maxillary bone in reptiles; even the outline of the anterior portion of the dentary piece is not traceable.

Teeth.—Capt. Brickenden informs me that when the fossil was discovered there were several extremely minute conical teeth, having a smooth polished surface; they were displaced, but distinctly visible. Under a highly magnifying power two or three displaced teeth are still discernible (Pl. IV. 1, 1 *a*, 2), but their original position in the jaw is not obvious. I have been unsuccessful in my attempts to make out the structure of the occipital condyle.

Vertebræ.—I cannot detect the atlas or axis; the first vertebra seen in Pl. IV. 9, is probably the third or fourth cervical; the spinal column from this point to the sacrum consists of twenty-four vertebræ, as in the Iguana, each bone bearing a pair of ribs. Whether the bodies of the vertebræ were concavo-convex, as in the Lacertians, or the reverse, as in the Salamanders*, or doubly concave, as in the living Axolotl (a Batrachian that inhabits the Lakes of Mexico), I cannot positively determine; but the sparry replacements of some of the intervertebral spaces appear to indicate the latter modification of structure: and if these casts exhibit the normal form, the vertebræ must have been deeply concave at both extremities: the length of a dorsal vertebra is one-ninth of an inch.

The vertebræ are for the most part exposed dorsally; that is, the upper part of the neural arch is deeply imprinted on the stone, in Pl. IV. 8: and sparry casts of the bodies of the bones constitute a portion of the spine in Pl. IV. 9.

A cast from the specimen, Pl. IV. 8, exhibits the form of the upper part of the vertebral column, so far as it can be determined from the

* In the *Salamandridæ* the vertebræ are convex anteriorly and concave posteriorly: the reverse of those of Frogs and Lizards: in the Axolotl they are deeply cupped at both ends.

fossils (see Pl. IV. 5, 6). In this point of view the dorsal aspect of the vertebra is of a subquadrangular form; the articulating planes of the zygapophyses are horizontal; the neural arch rises into a roof or dome, the spinous process forming only a slight ridge, and not a sharp crest, as in Lizards*. The body or centrum of the vertebra is cylindrical, slightly contracted in the middle, and both articular ends are concave: such at least is the inference I have drawn, after a careful consideration of the various appearances presented by the fragmentary remains of the spinal elements. If this view be correct, the characters of the vertebræ are peculiar: the centrum resembles that of the vertebræ in the Axolotl, and in numerous extinct Saurians, while the neural arch approaches the corresponding element in the Salamanders. A comparison of Pl. IV. 6, which is an enlarged view of the dorsal aspect of the neurapophysis of one of the fossil vertebræ, with the vertebra of the large Salamander, *Sieboldtia maxima* (Pl. IV. 7), for which I am indebted to J. E. Gray, Esq., shows this resemblance. Another remarkable feature of the spinal column in the fossil reptile is the great uniformity of character in the vertebræ throughout the spine. The sacral vertebræ are but indistinctly denoted: the caudals have long apophyses, and only ten or twelve vertebræ are disclosed, the terminal series being concealed beneath the stone; probably the entire length of the tail did not exceed an inch and a half.

Ribs.—The ribs, of which there are twenty-four pairs, are remarkably slender, and appear to have been attached by a simple head as in the Lizards; but, as only imprints of these processes remain, the mode of union with the bodies or neural arches of the vertebræ is not distinctly recognizable. Some of the impressions seem to indicate that the ribs were attached to a tubercle on the anterior part of the centrum: others may be traced to the middle, as if occupying the same relative position as in the Salamanders (see Pl. IV. 7); but the evidence on this point is very equivocal.

The length and curvature of the costal processes and the simple mode of attachment are lacertian characters, and strongly contrast with the usual abbreviated and rudimentary condition of the ribs in Batrachians; yet there is no proof that any of these processes extended forward to the sternum, or were united to thoracic or abdominal cartilages; on the contrary, the extremity of each rib appears to be entire, as if none of these bones were originally prolonged beyond the impressions left on the stone (Pl. IV. 9); and should future discoveries confirm the view above enunciated of the structure of the neural arch, it may be well to remind the reader, that in a genus of living batrachians, the *Pleurodeles*†, the ribs are developed almost to as great an extent as in this fossil reptile‡.

Pelvis.—On the specimen, Pl. IV. 9, the form of this part of

* In Lizards, after the twelfth dorsal vertebra the spinous process is a strong, well-marked character.—Cuvier.

† Pleurodeles, *Waltl*, Gray's Catalogue of Amphibia in the British Museum, p. 17.

‡ I am indebted to the eminent zoologist of the British Museum, John Edward Gray, Esq., for this reference; and also for unrestricted access to the important osteological collection which has been formed by his exertions.

the skeleton is indicated by a slight convexity, with an obscure median ridge; apparently produced by coalesced sacral vertebræ: on the stone, Pl. IV. 8, the corresponding impression is better defined, but there are no manifest outlines of the bones composing the pelvic arch. The subquadrangular depression in Pl. IV. 8 closely resembles that which would be left by the dorsal surface of the pelvis of the Salamanders; and under some points of view I thought there were perceptible traces of ilia and ischia resembling those of that family; but no reliance can be placed on this supposition. I have sought in vain for such impressions as the iliac bones of Iguanas or of other Lacertians or Saurians would produce; and I am not aware of any reptilian pelvis, except that of Batrachians, that could give rise to such an outline as is seen in Pl. IV. 5, 8, 9.

It may be proper to remark, that the pelvis is placed after the twenty-fourth vertebra as in the Iguana; in Batrachians the pelvic arch is usually attached from near the fifteenth to the eighteenth vertebra; but in the fossil Salamander of Œningen, it is situated near the twenty-first or twenty-second.

Pectoral arch.—Of this important element of the skeleton there are no vestiges exposed.

Anterior extremities.—Impressions of the distal half of the left humerus, and of the corresponding proximal portions of the ulna and radius (Pl. IV. 9) are the only indications of the anterior limbs, and these present no distinctive characters.

Hinder extremities. Femora.—Both femora (Pl. IV. 8, 9) have left distinct imprints, so that the form of the original can be made out. A restored outline is given in Pl. IV. 5. The femur has an oval head, a sharp process or trochanter on the inner side of the neck, and a subcylindrical shaft, the distal end of which is slightly expanded, and compressed in its antero-posterior diameter: the popliteal space and the two small condyles are seen in Pl. IV. 5.

Tibiæ and Fibulæ.—The forms of these bones are not perfectly defined by the imprints on the stone. The tibia has the shaft gently bowed, and expanded at each extremity; the corresponding fibula is a more slender bone: its entire shape is not seen.

Feet.—Unfortunately there are not the slightest traces of the bones of the feet.

The following measurements are added to give more precision to the above description:—

Cranium, length 8 lines.

Vertebral column, from the occiput to the pelvis, 2·4 inches.

Ribs, the longest 6 lines; equal to about the length of five dorsal vertebræ.

Femur, length 5½ lines. Tibia, length 4 lines.

Pelvis, transverse diameter 4 lines.

——, antero-posterior diameter 3 lines.

As the drawings are of the size of the original, further particulars are unnecessary.

The above statement comprises eve[illegible]ical character of this

Devonian Reptile, which a patient investigation of the specimens has enabled me to detect; the details have been worked out by the aid of models of those bones that have left distinct imprints, and by this method the form of the dorsal aspect of the neurapophyses, and of the bodies of the vertebræ, the femora, &c., as represented in Pl. IV. 5, were determined.

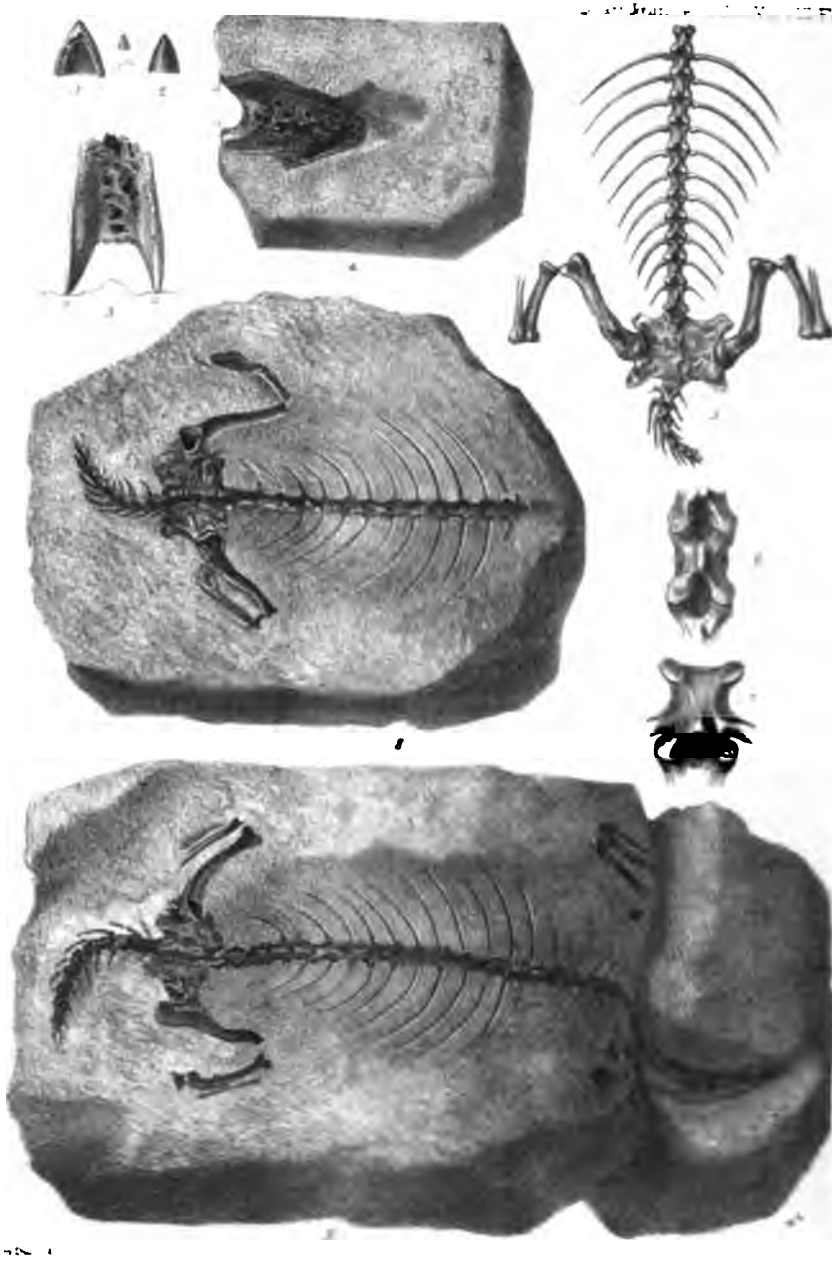
On the accuracy of the descriptions the palæontologist may rely, for they have been drawn up with due caution and are faithfully recorded; but the following observations on the probable affinities of the original animal are offered with much deference, and as mere approximative inferences, the true value of which the discovery of a skeleton, or even of detached bones, will sooner or later determine.

The structure of the skeleton, so far as it is disclosed by the specimens submitted to my examination, indicates a peculiar type of reptilian organization, in which, as in numerous other extinct forms of this Class, osteological characters are associated, which in existing oviparous quadrupeds are restricted to distinct orders or genera. Such anomalies (as our preconceived archetypal notions lead us to regard them) are continually presented to the palæontologist, and often embarrass his attempts to interpret the relics of beings whose races have long since been swept from the face of the earth.

The skeleton from Elgin exhibits lacertian characters with batrachian modifications. From the mutilated condition of the imperfectly exposed cranium, the feeble imprint of the lower jaw, and the uncertainty as to the mode of implantation of the teeth, no conclusive opinion can be formed as to the construction of the skull; the oval or oblong form of the head may belong either to a Lizard, or an aquatic Salamander. In the length and characters of the ribs, the situation of the pelvis, and the well-developed limbs, the fossil exhibits lacertian or varanian affinities; but the apparent structure of the neural arch with its small spinous process, and the horizontality of the articular surfaces of the zygapophyses, and the shape of the impression left by the pelvic arch, are suggestive of batrachian characters; and in regard to the extent of the ribs, the fact that in the *Pleurodeles* the costal processes are not rudimentary, as in other batrachians, renders that feature less decisive.

In the absence of any certain knowledge of the essential characters of the cranium, jaws, and mode of dentition, and with no traces of the bones composing the pectoral arch and feet, and with but faint indications of the structure of the pelvis, I cannot presume to refer the fossil reptile to any existing order. The difficulties which beset the determination of the natural relations of extinct reptilians, of which even the skull, teeth, and jaws, and many other parts of the skeleton, are known, is strikingly exemplified by the fact, that at the present time the Labyrinthodonts, which in England are generally considered to be true batrachians, are regarded as saurians by many eminent foreign palæontologists (Von Meyer, Plieninger*, Pictet, &c.); and the

* The Labyrinthodonts are divided by these authors into three genera, viz. *Mastodonsaurus* (of Jäger); *Capitosaurus*, and *Metopias*. See 'Beiträge zur Paleontologie Wurtembergs.' Stutgard, 1844.



original name of *Mastodonsaurus* is actually restored to the great Wurtemburg reptile, discovered by my friend Dr. Jäger of Stutgard. In fact, the characters of the batrachian order are chiefly derived from the soft parts, of which no traces occur in a fossil state; and it is consequently impossible to determine with precision whether remains of reptiles of extinct types, and of whose early condition we are in utter ignorance, are referable to saurians or to batrachians.

From what has been advanced, I am led to conclude that if future discoveries should prove the batrachian character of the reptile of the Old Red of Scotland, the original must have nearly resembled in general form, and doubtless also in its habits, the Tritons or aquatic Salamanders; but that it had a longer and broader dorsal region, a wide tail, and well-developed limbs, equally adapted for progression on the land or through the water: on the other hand, should its lacertian relations be established, it probably differed but little in its physiognomy and economy from the small existing terrestrial Lizards, its length not exceeding six or seven inches.

In the uncertainty as to the natural relations of this most ancient skeleton of an oviparous quadruped hitherto discovered, I propose to distinguish the Devonian reptile of Scotland by a term simply denoting its remote antiquity, viz. TELERPETON (τῆλε, *procul*; ἑρπετὸν, *repens*), with the specific designation of *Elginense*, to record the locality whence it was obtained.

DESCRIPTION OF PLATE IV.

Illustrative of the TELERPETON ELGINENSE (Mantell), a fossil Reptile from the Old Red Sandstone of Morayshire. The original is in the collection of Peter Duff, Esq., of Elgin.

Figs. 1*a*, 2. Enlarged views of very minute conical teeth seen in the portion of cranium represented in figs. 3 and 4.

Fig. 1. Enlarged view of a fractured tooth showing a relatively large internal cavity.

Fig. 3. Imprints of the posterior part of the two rami of the lower jaw, with vestiges of minute teeth, and the palatal arch of the skull, seen from beneath, as exposed in the piece of stone, fig. 4. The form of the anterior part of the head and lower jaw is not obvious. *a*, *a*. The impressions of the posterior angles of the lower jaw.

Fig. 4. The remains of the cranium, imbedded in the fragment of stone, fig. 4*, as seen when separated from the block, fig. 9.

Fig. 5. Restored outlines of part of the vertebral column, pelvis, bones of the hinder extremities, &c.

Fig. 6. Enlarged view of a dorsal vertebra of the TELERPETON, with the anterior and posterior zygapophyses of the contiguous vertebræ.

Fig. 7. Dorsal vertebra of the large Salamander (*Sieboldtia maxima*), to show the general resemblance of the neural arch and the zygapophyses to those of the *Telerpeton*.

Fig. 8. A portion of sandstone struck off from the larger block (fig. 9), in the direction of the plane of the spinal column. It exhibits the imprint of the dorsal aspect of the skeleton.

Fig. 9. Impression of the skeleton of TELERPETON ELGINENSE, natural size, showing the outline of the vertebral column, ribs, pelvis, femora, tibiæ and fibulæ, part of the caudal series of vertebræ, the left humerus, radius and ulna, imperfect traces of the right anterior extremity, and obscure indications of part of the cranium.

On the supposed Fossil Eggs from the Devonian Rocks of Forfarshire.

In connection with the announcement of the discovery of fossil reptiles in the Old Red of Morayshire, I would offer a few remarks on certain organic remains that occur in the more ancient Devonian strata of Forfarshire, and which are popularly termed "petrified blackberries," and have been considered by some naturalists to be seeds, by others the ova of gasteropodous Mollusca.

These fossils are small, carbonaceous, oval bodies, more or less depressed, and are figured by Sir Charles Lyell with the following observations* :—

"In the same grey paving-stones and coarse roofing-slates in which the *Cephalaspis* occurs, in Forfarshire and in Kincardineshire, the remains of marine plants or fucoids abound. They are frequently accompanied by groups of hexagonal, or nearly hexagonal, markings, which consist of small carbonaceous bodies placed in a slight depression of the sandstone or shale. These much resemble in form the spawn of the recent Natica, in which the eggs are arranged in a thin layer of sand, and seem to have acquired a polygonal form by pressing against each other. The substance of the egg, if fossilized, might give rise to small pellicles of carbonaceous matter. These fossils I have met with both at the foot of the Grampians, north of the valley of Strathmore, and in the vertical shale beneath the conglomerate, and in corresponding beds in the Sidlaw Hills; always occupying the same situation, and without any intermixture of shells, whether marine or freshwater."

Several years ago my attention was directed to this subject from having obtained, from some indurated mud thrown up from the bottom of a long dried-up pond on Clapham Common, a carbonized mass of the ova of a Frog (*Rana temporaria*), which so closely resembled the petrified eggs of Forfarshire, that I suggested to Sir Charles Lyell the much greater probability that the latter were referable to batrachians than to gasteropodous mollusks; but, although the analogy was admitted, the fact that no traces of reptiles had at that time been discovered in any formation more ancient than the Trias, was regarded as fatal to such an interpretation.

On receiving the fossil reptile from Elgin, the idea of the batrachian origin of the "petrified blackberries" again recurred to my mind, and from a careful examination of all the specimens within my reach, and a comparison of the fossil ova with those of the Frog in a carbonized state, I have no hesitation in expressing my conviction, that if the *animal origin* of the carbonaceous bodies found in the shales of Forfarshire be proved, there is no doubt that they are the ova of batrachians closely allied to the *Ranidæ* or Frog tribe.

The fossil eggs occur in clusters blended with the foliage of apparently fluviatile plants. Their forms are in many instances well defined, and the polygonal depressions or cells left by the bursting

* Manual of Elementary Geology, 3rd edition, p. 344.

and removal of the ova are distinctly shown; and they entirely correspond with those in the recent carbonized mass from Clapham.

Fig. 1. Fig. 2.

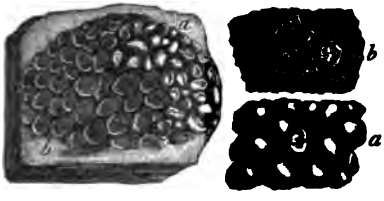


Fig. 1. *Slab of Old Red Sandstone, Forfarshire, with eggs of Batrachians?*

a. Ova in a carbonised state.
b. Egg cells; the ova having been shed.

Fig. 2. *Eggs of the common Frog,* Rana temporaria, *from a dried-up pond in Clapham Common.*

a. Portion of the ovary.
b. A transverse section of the mass exhibiting the form of the egg-cells.

Fig. 3.—*Devonian Shale, Forfarshire, with impression of Plants and Eggs of Batrachians?.*

a. Two pair of ova resembling those of large Salamanders or Tritons on the same leaf.
b, b. Detached ova. *c*. Egg-cells of Frogs?

[The use of the above woodcuts has been kindly granted by Sir C. Lyell.]

Associated with these remains are small, oval, roundish bodies, disposed singly or in pairs among, and sometimes adherent to, the foliage with which they are collocated; these fossils so strikingly resemble the eggs of aquatic Salamanders, that, admitting the batrachian character of the specimens previously described, there is every reason to conclude they are the mineralized ova of reptiles, which, like the recent Tritons, deposited their eggs on the leaves of aquatic plants.

Aware how startling such a statement might appear to those who had not examined the evidence on which it is founded, I requested my friend Mr. Newport, our eminent physiologist, whose profound investigations of the development of the ova in the *Amphibia* have recently received the award of a Royal Medal, to allow me to place before him the facts which bear on this question; and I am permitted to state that, after a careful investigation of the fossil and recent ova, Mr. Newport concurs with me in the opinion that the carbonized eggs in the Devonian shales of Forfarshire are referable to Batrachians; those which are in clusters, and in size and form and arrangement resemble the spawn of the Frog, belong to *Ranidæ*; while the larger ova that occur singly or in pairs, and are attached to leaves, are probably those of large aquatic Salamanders. It may be observed that

Sir Charles Lyell remarks, that from the *entire absence of shells* in the grey shales and slates that underlie the conglomerate of the Old Red of Forfarshire, he found no fossils so useful in identifying the beds as these ova. The *Cephalaspis* occasionally occurs in the same strata; but, assuming these eggs to be batrachian, the remains of fishes are absolutely as nothing in comparison with the myriads of vestiges of aquatic reptiles that are scattered through the Lower Devonian deposits of Forfarshire and to the north of Fife.

Thus, for the first time, we have obtained certain proofs of the existence during the Devonian epoch of several orders of the class *Reptilia*, of which (with the exception of the supposed chelonian foot-prints in the Lower Silurian) no indications were known in any formation more ancient than the Carboniferous.

In the *Telerpeton Elginense* (and whether the original were a lacertian or a batrachian is of no importance whatever in a geological point of view) we have indisputable evidence of the presence of air-breathing oviparous quadrupeds, bearing a general resemblance to the Lacertians or Salamanders of modern times.

The quadrupedal foot-tracks discovered by Capt. L. Brickenden—according to the accepted interpretation of similar imprints by palæontologists—denote the existence of terrestrial Chelonians or Tortoises contemporaneously with the *Telerpeton*. The ova in the shales of Forfarshire carry back the reptilian fauna to a yet remoter period, and afford presumptive proof that the rivers and streams of the Devonian ages swarmed with Frogs and Tritons; and the occurrence of these remains with those of fluviatile plants, and of ganoid fishes (which, for aught we know to the contrary, may, like the *Lepidostei* of the American rivers, and the *Polypteri* of the Nile, have been inhabitants or frequenters of fresh water), together with the absence of shells and casts of shells, suggests the probability that the strata in which these fossils are distributed may be of lacustrine or freshwater origin.

I refrain from indulging in any comments on the bearing of these discoveries on the problems relating to the successive appearance of distinct types of organic life on the surface of our planet, as indicated by the fossil remains discovered in the respective formations; yet I cannot conclude without reminding the Society, that but a few months have elapsed since our late President, Sir Charles Lyell, in his last Anniversary Address, with the view of restraining the rash and hasty generalizations of those who would fix the first creation of each tribe of plants or animals, or even of animate beings in general, at the precise point where our retrospective knowledge happens to stop, emphatically remarked that "our acquaintance with the living creation of given periods of the past must depend in a great measure on what we commonly term chance; and that the casual discovery of new localities rich in peculiar fossils, may modify or entirely overthrow all our generalizations which are based on the supposed non-existence at former epochs of the fossil representatives of large families or classes of plants and animals*."

* Quart. Journ. Geol. Soc. 1851, vol. vii. p. lxviii.

And now, ere another Anniversary has arrived, the casual researches of two gentlemen in the Old Red Sandstone of a remote part of Scotland have brought to light memorials of the past which establish the existence, during the Devonian epoch, of several orders of a higher class of *Vertebrata* than had previously been discovered; and this evidence is so complete and incontrovertible, and affords such an unexpected and striking confirmation of the truth and sagacity of the salutary caution enunciated by our late President, that his warning assumes the character of a prediction, the fulfilment of which may possibly be not very distant.

It only remains for me to express my warmest thanks to my friend Capt. L. Brickenden, and to Mr. Patrick Duff, for enabling me to have the pleasure and privilege of communicating to the Geological Society an account of one of the most interesting and important discoveries in British Palæontology which it has ever been my good fortune to record.

Chester Square, November, 1851.

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2. *Notice of* Fossil Bones *at* Portland. By Mr. A. Neale.

[From a Letter to the Sec. G.S.]

In making a road for the conveyance of stone for the construction of the Breakwater at Portland, a cutting has been opened to the depth of about 30 feet from the surface of the island, which is here about 400 feet above the sea-level. The rock (here covered by a superficial deposit, which is red below and darker at the top) is extensively fissured in every direction, the cracks being from 1 to 6 inches wide, and occupied by a deposit differing from the superincumbent soils. The rock also is here traversed by a cleft, 10 feet wide, running in a S.W. and N.E. direction, and containing large round black blocks of stone, fragments of bone, and teeth*, imbedded in a black sand.

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3. *On the* Sub-escarpments *of the* Ridgway Range, *and their* Contemporaneous Deposits *in the* Isle *of* Portland, By Charles Henry Weston, Esq., Barrister-at-Law, B.A. Cantab., F.G.S.

[The reading of this Paper in full was deferred until the next Evening Meeting.]

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* A molar tooth of a Horse from this deposit was forwarded with the letter.

JANUARY 21, 1852.

The following communications were read :—

1. *On the* SUB-ESCARPMENTS *of the* RIDGWAY RANGE, *and their* CONTEMPORANEOUS DEPOSITS *in the* ISLE *of* PORTLAND. By CHARLES HENRY WESTON, Esq., Barrister-at-Law, B.A. Cantab. F.G.S.

SINCE I had the honour of presenting to the Geological Society some remarks on the nature and superposition of the formations at Ridgway*, I have had another opportunity of examining that locality, and the following are the conclusions to which I have been led.

I. That the entire valley of Upway, although disturbed, is yet one of *denudation* and not a *synclinal trough*, as hitherto considered.

II. That the section of the Ridgway cutting† exhibits, more or less, the normal structure of the whole range.

III. That my views respecting the extension of the Purbeck group to the most westerly limits of the Corton Hill‡ and Whaddon Ridge, have been confirmed; and

IV. That the same Formation, on the other side of the great anticlinal axis of this district, does not terminate at the centre of the Isle of Portland, but exists also at the Bill, its most southerly point.

Before entering upon the subjects under consideration, it will be necessary to bear in mind that the elevated land of Ridgway bounds the Upway Valley on the *north* side, and is composed of local patches of tertiary deposits, and of chalk and greensand, with subjacent Wealden and Upper Oolite; while parallel to this, on the *south* side, ranges a steep Hogsback, consisting of the Purbeck and Upper Oolitic groups only. This southern ridge, although evidently once continuous, is now cut through by transverse gorges and valleys, (See Map, fig. 1) resulting, as the geological features of the country seem to indicate, from long-continued action of the then existing sea.

The following selected sections on the southern sub-escarpment will be sufficient to convey an idea of the internal structure of this range. They commence a little east of the railway embankment, and are to be found as we proceed westward to its termination near Portisham.

1§. *Portland Oolite* (with *Ammonites* and *Trigoniæ*): double dip.—One to N. by W. at the high angle of 40°, and the other to N.E. by E. at 20°. The valley in parts cut down to the Portland sand.

2. The Purbeck and Portland formations are here brought into juxtaposition, as shown in the diagram, fig. 2.

3. Crest of hill.—*Purbeck*: dip to N.N.E. at 20°. Upway Valley apparently cut down to the Portland oolite.

4. Crest of hill.—*Purbeck*: dip to N. by E. at 20°.

* Quart. Journ. Geol. Soc. vol. iv. p. 245, and vol. v. p. 317.

† See also Quart. Journ. Geol. Soc. vol. iv. p. 249.

‡ Quart. Journ. Geol. Soc. vol. v. p. 318.

§ The numbers refer to the sections marked on the ground-plan of the district, given in the Map, fig. 1.

5. At a lower level than sections 3 and 4.—*Portland oolite*: dip to N. by E. at 20°.

6. At a lower level than No. 5, at Corton Gorge.—Base of *Portland oolite*: dip to N. by E. at 12°. Portland sand is exposed below.

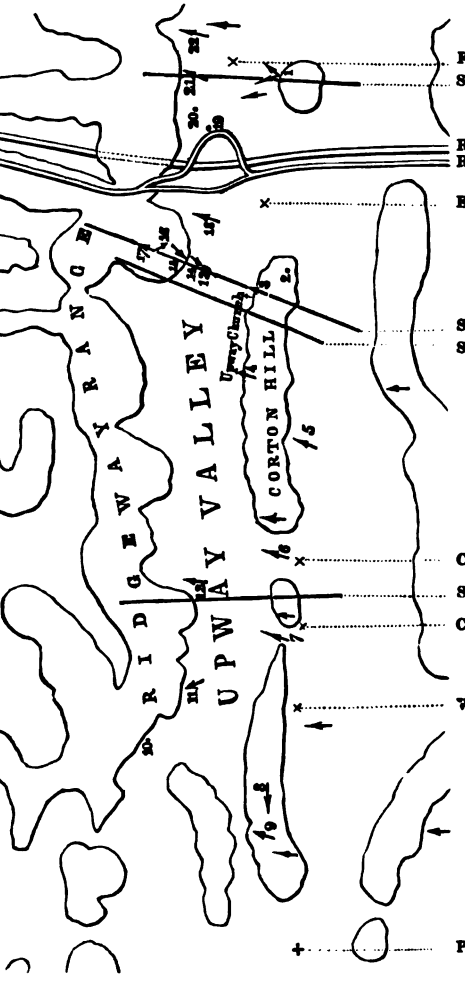


Fig. 1.—*Outline Map of part of the Ridgway Range and its Subescarpments.*
Scale 1 inch = 1 mile.

The transverse valleys that run at right angles out of the Upway Valley are shown at Coryates, Corton, and Elwell.

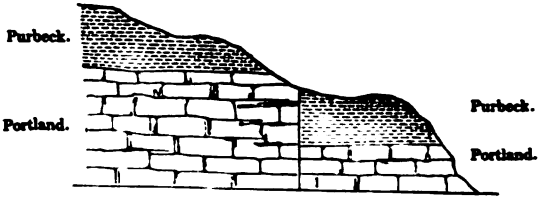
The "Dips" that have numbers attached are those referred to in the Paper; those without numbers are taken from the map of this district by Dr. Buckland and Sir H. T. De la Beche, in the Trans. Geol. Soc. 2 Ser. vol. iv. Part I.

N.B. Section 19 should be on the W. of the railway and near the old road; and Sections 20, 21, and 22 should also be placed further to the W. Section 23, inadvertently omitted, is immediately south of the farm-house.

7. Coryates Gorge.—Strata denuded to the commencement of the Kimmeridge clay. No Purbeck appears on the crest of the hill for some distance. *Portland oolite*: dip to N. at 10°.

8. Crest of hill.—*Purbeck*: dip to W. at 5°.
9. Crest of hill.—*Purbeck* (2 quarries): dip to N.E., 5°–10°.

Fig. 2.—*The Fault seen at Sect. 2.*



Observations on the sections of the southern sub-escarpment.

1. Shows not only the greatest inclination of strata in a direction generally common to the entire range, but also a co-existing dip to the E. This section exhibits a local subsidence.

1 to 9. Show in the aggregate a gradual decrease of dip from E. to W., evidencing sect. 1. as marking the region of the greatest disturbance (see fig. 9).

2. Shows a downcast fault; an examination, however, of the whole range leads to the conviction that this is not the result of disturbance, strictly so called, but rather of a slip occasioned by the subtraction of part of the Kimmeridge clay (on which the hill is based), by the action of the then contiguous sea. This forms one of the indications before alluded to, of the *continued* nature of the water-action then in operation.

5. In this quarry, amidst the lines of black flinty masses, which so characterize the Portland oolite, I found wood partly silicified and partly retaining carbonaceous matter, as well as the remains of a tree, apparently exogenous, about 18 inches in diameter.

2 to 9. Show that wherever the crest of this entire southern ridge has not been denuded, *the Purbeck is found resting conformably upon the Portland oolite as far as its most westerly limit.*

The western extremity of the valley has very little depth and rather merges in the hills. In denudation, we may consider the valley as affected to the *Purbeck* in the west; further east, to the *Portland oolite*; and at section 1, to the *Portland sand*; *i. e.* it appears to deepen progressively from west to east; this is illustrated by the accompanying diagrams (figs. 3, 4, 5, and 6). Sections 6 and 7 do not negative this conclusion, because these refer to the N. and S. transverse gorges, and not to the great Upway Valley at right angles to them.

We have now to examine the base of the chalk-range on the *north side* of the Upway Valley, and I shall subjoin (in brief) such sections as are necessary to render intelligible its stratigraphical details, taking an opposite direction, from west to east, and ending on the east at the farmhouse north of section 1.

10. *Purbeck*, containing apparently *Cyrena* or *Cyclas*: dip not visible.

11. *Purbeck*: dip to N. at 12°.
12. *Purbeck*: dip to N.N.E. at 12°.
13. (N. of Upway Church) *Purbeck*: dip to N.E.

Figs. 3, 4, and 5.—*Transverse Sections of the Upway Valley at three different points along its extent* (see Fig. 6, and the Map, Fig. 1).

Fig. 3.—*The denudation reaching to the Purbeck beds.*

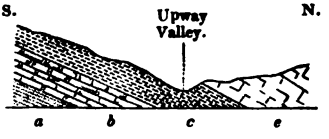


Fig. 4.—*The denudation reaching to the Portland Oolite.*

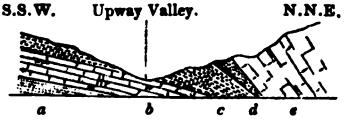
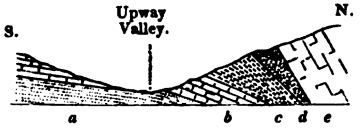


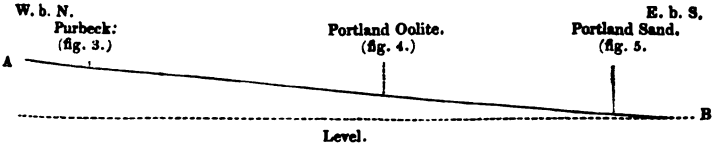
Fig. 5.—*The denudation exposing the Portland Sand.*



a. Portland Sand.
b. Portland Oolite.
c. Purbeck beds.
d. Hastings Sand and Clay.
e. Chalk.

Fig. 6.—*Longitudinal Section of the Upway Valley.*

Length about $3\frac{1}{2}$ miles.



A B, the valley from N. of Whaddon to a little W. of the Farmhouse.

14. (N. of 13) *Purbeck*: with the dip *reversed*.
15. (N. of 14) *Purbeck*: dip to S.W. at 12°.
16. (N. of 15) Two quarries of *Purbeck*: dip to S.E. at 22°.
17. (N. of 16) *Chalk*: dip to N. by W. at 8°*.

* I did not see this quarry in 1847; but this dip of the chalk to the N. is quite in accordance with the views I then took of the inclination of the whole chalk range to the N.

The annexed diagram, fig. 7, will give the general bearing of the N. and S. line of sections 14, 15, 16, and 17, and also their relation to section 3, on the S. side of the valley, before detailed.

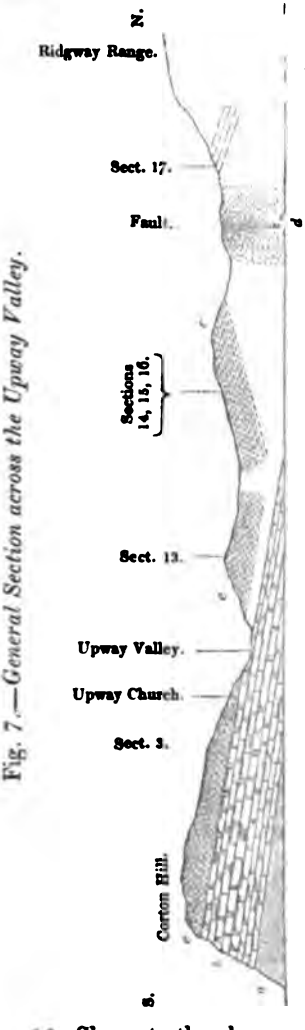


Fig. 7.—*General Section across the Upway Valley.*

In this section I have inserted the Hastings sand (*d*) hypothetically. I found on the north of the Purbeck sections, and between the Purbeck and the Chalk, a slight depression of the surface, watered by a streamlet and boggy. It seems, therefore, very probable, looking at the stratigraphical details of the locality, that there has been a severance of the Purbeck and the overlying formation, giving rise to this flow of water; and the boggy state of the ground would also mark an argillaceous deposit, which is the character of that portion of the Hastings sand above the Purbeck, in the same relative position one mile further east at Ridgway.

18. (E. of last section) *Purbeck*: dip to N. by E. at 6°, and so in the next field as far as it could be made out.

19. (E. of old Ridgway road) *Purbeck*: dip to W.N.W. at 5°.

20. *Purbeck*: dip to N.N.W.

21. *Portland*: dip to N. by E. at 15° to 20°.

22. *Purbeck*: dip to N. by E. at 30°.

23. *Purbeck*: dip 55°.

Observations on the sections of the Range N. of the Valley.

10 to 12. Show the west part of the valley to possess great regularity of dip (to the N.).

14 to 16. Lead in this case to the inference of the subsidence of the strata at Upway, resulting from a local fracture of the Purbeck on its general upheavement.

19. Shows to the observer of this large quarry a dip towards the old Ridgway road,—a dip which here coincides in a great degree with the natural dip of the country.

21 and 23. Show an alteration in the direction of the dip with an inclination increasing to the E., and reaching its maximum at section 23.

23. Besides the dip to the N., this section points to a fall of the strata coinciding with the surface-dip of the country.

General deductions to be drawn from the sections unitedly.

These in the aggregate (with few exceptions) give on *both* sides of the valley a dip to the N., and even the apparently anomalous sections (14, 15, and 16) do not in any way affect the main question, because the strata of that part of the Purbeck series which really forms the Upway Valley, have the same normal bearing. The local subsidence of the strata lies in fact beyond the limits of the valley.

The Purbeck beds have been shown to crop out along the base of the northern range, and then to cap the southern, just in the natural direction of the strata when they were continuous.

The capping consists of outliers of the Ridgway Purbeck beds,—or rather, is an almost unbroken extension of those beds from Upway to the termination of the Portland range at Portisham.

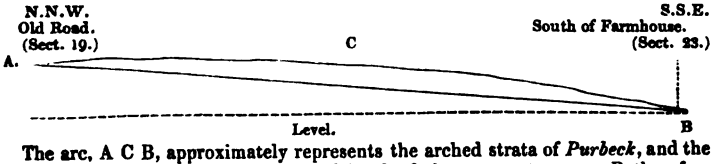
The valley does not present any symptoms of longitudinal disturbance, but, as far as observation extends, discloses in its hollow such different parts of the Wealden and Upper Oolitic rocks as we should *à priori* expect to find.

We may therefore infer conclusively that the strata of the Upway Valley have been cut down to their present level by aqueous abrasion. The valley is strictly *a valley of denudation*.

The general evidence of all the sections and the vertical section right across the valley, given under sect. 17, concur in proving that the great section of the Ridgway cutting (fig. 8) may be considered a type of the common structure of the Upway Valley.

Sect. 23 [not on the map,—it is to the S. of, and close by, the farmhouse] is N. of sect. 1, and these two have a coincident dip forming the depression near the farm-house. This depression I found barometrically to be about 60 feet below the level of the same strata in the Ridgway cutting. Sections 19 and 1 show also dips in opposite directions, so that sect. 19, together with 1 and 23, indicate respectively the W. and E. extremes of a geological arch, and point to the E. part of the valley as a locality of disturbance. The depression near the farm is therefore what I hesitatingly suggested in 1848, "not merely external, but essentially connected with the stratification below."

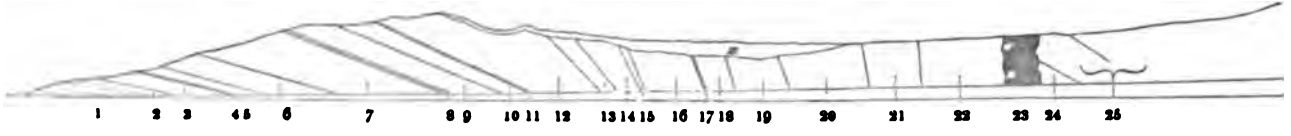
Fig. 9.—*Diagram showing the arched strata between the old Ridgway Road and the Farmhouse, and exhibiting the region of the greatest disturbance at the base of the Ridgway Range.*



The arc, A C B, approximately represents the arched strata of *Purbeck*, and the chord, A B, the relative difference of level of the two extremes. B therefore shows the local subsidence. The flexure of the strata, as stated in the details already given, increases from A to C, and then in a more rapidly increased ratio from C to B.

Fig. 8.—*Section along the Railway Cutting on the South side of the Ridgway Hill.*

S. Scale 400 feet = 1 inch. The inclination, shown by the oblique longitudinal line, is 28 in 2520 feet. N.



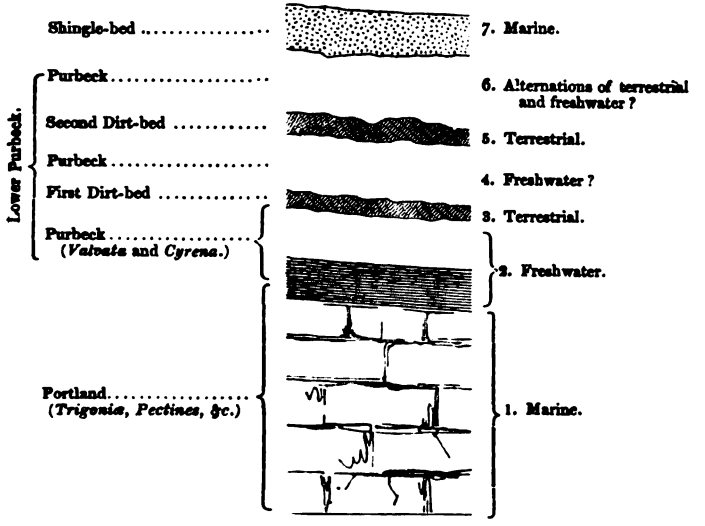
		Feet.	In.
"Portland."	1. Marl-rock, with seams of flint (*Perna, Cardium dissimile, Trigonia gibbosa, Panopæa, Pleurotomaria*)...	15	0
	2. Sand-rock (*Perna*)	3	0
	3. Sand-rock, clays, and marls, with some chert	13	0
	4. Chert (*Valvata, Paludina*)	1	0
	5. Sand and clays	8	8
	6. Variegated sandy clays (*Cypris*)	23	0
	7. Sand-rock, marls, and clays	28	11
	8. Sand-rock (*Cypris*)	3	3
	9. Marls, sand-rock, and alternating marls and clays ...	19	8
	10. Sand-rock and clays (*Cypris, Cyrena*, and Univalves).	13	9
	11. Limestone (*Ostrea*)	3	4
	12. Clays, sand-rock, marls, and limestone (some beds with *Cyrena, Cypris*)	32	8
	13. Irregularly laminated clays and fibrous carbonate of lime	8	0
	14. Marl, sand-rock, and limestone (some beds with *Cyrena, Cypris*)	16	9
	15. Sand-rock	5	0
	16. Sand-rock, clays, and marls (*Unio*, &c. in some beds)	41	6
	17. Indurated marl	1	6
	18. Clays (*Unio*, and woody carbonaceous matter)	30	0
	19. Grey, white, and yellow sands (woody carbonaceous matter).....	50	0
	20. } Coloured sands and loams.		
	21. }		
	22. White sand.		
	23. Fault. Oxford Clay, with blocks of Cornbrash.		
	24. Greensand.		
	25. Chalk.		
	x. Superficial deposit.		

The beds from 1 to 19, inclusive, are represented as laid down in a Section taken along the Railway-cutting at Upway by Captain Ibbetson, F.G.S., for the Ordnance Geological Survey; Sir H. De la Beche having kindly allowed a reduced copy of the Section to be made for the illustration of this Paper. The beds numbered 20 to 25, including the Fault, are put in without measurements.

We must now refer to the contemporaneous Purbeck beds in the Isle of Portland.

Former sections* have shown that the Isle of Portland dips away to the S., so that the high escarpment on the N. diminishes to a mural cliff, very little elevated above the sea-level, at the Bill. This extremity I examined for the express purpose of determining whether my suspicions of the extension of the Purbeck so far South, which my hurried visit in 1847 had led me to entertain, were correct or fallacious; and I now found on its western side an unequivocal section of the junction of the marine and freshwater strata, as in the accompanying sketch.

Fig. 10.—*Section of part of the Cliff at the Bill of Portland.*



No. 1 is the Portland formation. It is quarried down to nearly high-water-mark, and abounds, from the lowest portions to within a short distance from its junction with No. 2, with remains of marine lamellibranchiate molluscs. The beds which are immediately below the Purbeck in the northern part of the island, are, on the other hand, equally marked by a profusion of gasteropodous molluses.

No. 2. This stratum is not very decidedly separated from No. 1, and its equivalent in the quarry containing such numerous casts and impressions of gasteropods is lithologically a *bonâ fide* portion of the subjacent and unquestionable marine deposit. The strata 1 and 2 appear *in situ* to have been continuous and of common origin. Prof. E. Forbes has, however, in his valuable paper "On the succession of strata in the Dorsetshire Purbecks†," clearly proved that there is no

* Trans. Geol. Soc. 2nd Series, vol. iv. pl. 2.

† Rep. Brit. Assoc. 1850, Transact. Sect. p. 79. Edinb. New Phil. Journ. vol. xlix. 1850, p. 311.

passage from the Portland into the Purbecks; that "the top beds of the Portland stone are purely marine, and the lowermost beds of the Purbeck are purely freshwater, containing *Cyprides*, *Valvata*, &c." The true nature of No. 2 consequently involved the questions of the gradual or abrupt succession of the Purbeck group—whether the dirt-bed (No. 3) reposed directly upon the Portland Oolite, or whether here, as elsewhere, there was a freshwater bed intercalated between the lowest dirt-bed and the Portland. This case could alone be decided upon by palæontological evidence, and Prof. E. Forbes most kindly undertook to examine the fossils. "After a close examination of the specimens sent (writes Prof. F.), my impression is that they are of freshwater origin, and belong to the lowest beds of the Purbeck series, and contain *Valvata* and *Cyrena*."

I have consequently marked No. 2 as Purbeck; the apparent discrepancy between the mineral and fossil evidence thus adduced may I think be easily reconciled.

It will be seen that the beds (4 and 6) were either originally formed, or (subsequent to their deposition) structurally modified, by chemical forces; No. 2 has also a compact and subcrystalline texture indicating similar chemical influences. Now it is very easy to conceive that after the elevation of the Portland oolite above the sea, the Purbecks may have been forming upon *the yet unindurated* surface of the Portland, and that after the deposition of the beds exhibited in the section the permeating gases, absorbed by water, could not only impart to No. 2 its subcrystalline character, but convert and cement the lowest Purbeck and the uppermost Portland (both calcareous rocks) into one homogeneous body The induration of aqueous strata, depending as it does, not merely upon the absorption of carbonic acid gas, but (among other things) upon the loss of watery particles, could not have proceeded while the upper oolites remained submerged, and, as we know not what period elapsed between the formation and elevation of the Portland, the view I have suggested is not at all incompatible with that evolution of time which must have occurred between the Oolitic and Wealden æras.

3 and 5. These are true dirt-beds, and fossilized trees have been found in them.

4 and 6. These Purbeck beds appear to me to have been originally formed by deposition from water charged with carbonic acid gas. They are decidedly tufaceous.

As I did not procure positive evidence of either the fresh or brackish water character of these beds, I have marked them accordingly. Most probably, however, they will prove to be freshwater.

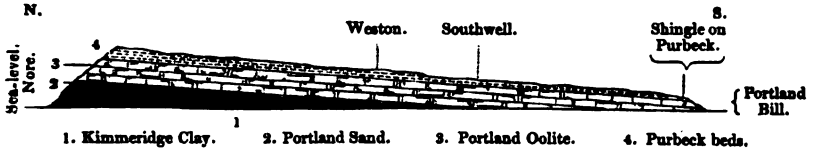
6. This bed has carbonaceous alternations at the upper part, showing on a minute scale the oscillations of the then existing surface during shorter intervals of time.

7. This remarkable bed consists of beach-pebbles (with a few chalk-flints), rounded by continued sea-action. The quarryman said it extended about ¼ mile North of the Bill.

It is to be remarked that the surface of the island, when carefully examined, does not dip regularly down towards the South, like an

inclined plane, but, after passing Weston (see fig. 11), the surface rather sinks down by terraces to the Bill, so that streams are constantly flowing to the South from the bassett-edges of the Lower Pur-

Fig. 11.—*Longitudinal Section of the Isle of Portland.*



beck strata. These features have doubtlessly resulted from partial denudation. The superficial covering of beach-pebbles proves a co-existing and co-extensive sea, and their rolled character equally points out the long period during which the sea must have acted on the Southern part of the island. But the *local* extent of the beach seems also to show that the Northern portion of the island was standing fully emerged from the ocean, while the Southern was still under its influence. May we not, therefore, infer from these premises that the Island of Portland has experienced an elevatory movement *subsequent* to that which it felt in common with the whole Weymouth district? For, as by the protrusion of the great boss of Forest Marble the Northern extremity of the island was tilted up, leaving the Southern portion a littoral region, so there must have been a *second* upheavement, by which the Southern part was elevated and enabled to carry up to its present height on the shoulders of the Purbeck the beach-pebbles of the bed No. 7, fig. 10.

We have seen that the Purbeck formation does not stop at the centre of the island, as hitherto considered, but exists also at its most Southern extremity; and I believe, from the specimen of fossilized wood which I saw near the Government Railway on the N.E. side of the island, and which I was told, on good authority, came from a neighbouring quarry, and from the nature of the ground over which I walked on my way to the Bill, that the Purbeck will ultimately be found to be co-extensive with the entire subjacent Portland oolite.

In conclusion, I would observe that the Isle of Portland affords an instructive view of the rise of rivers, and may enable us to speculate upon the real geological locality of the river Wey at Upway.

In Portland we have confessedly a mass of land completely isolated, and yet, on proceeding Southward beyond Weston, we find, as already noticed, copious springs. It will be evident by a reference to a section of that island (see fig. 11), that these springs could not possibly have a source beyond the North escarpment, both from the structure and the stratification of Portland; and yet we see that this limited region, with the acknowledged laws of the atmosphere and caloric in relation to capacity for absorption of moisture, affords an ample apparatus for the production of perennial streams by unceasing condensation of aqueous moisture.

Now the River Wey wells up from the Portland Oolite at the North

base of the Corton range, at Upway, and, while the rise is indeed from several spots, a careful observer may remark that many of these spots lie in straight lines, following, as I conceive, the lines of stratification. This range too, although inland and apparently connected with contiguous hills and valleys, is nevertheless *geologically as isolated as the Isle of Portland*; and as we know its longitudinal terminations, its inclination of strata dipping towards the Upway Valley in which the river rises, and its high and abrupt escarpment towards the channel, we can have no hesitation in considering (after what has been observed in Portland) that the source of the River Wey is connected with the Corton range *exclusively*.

Lastly, as the Corton range did not receive its present physical features until the Tertiary age, it is evident that the present River Wey has been only called into existence during that comparatively recent geological period.

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2. *On the* "QUARTZ ROCK" *of* MACCULLOCH'S MAP *of* SCOTLAND. By DANIEL SHARPE, Esq., F.R.S., V.P.G.S.

AMONG the many Formations of Scotland which are still involved in obscurity, *Quartz Rock* causes the greatest trouble to geologists exploring that country; and yet the obscurity does not arise from neglect. Dr. MacCulloch published a paper on the subject in the second volume of our Transactions, devoted a chapter to it in his masterly work on the Western Isles*, described and arranged all its varieties in his "Classification of Rocks," and laid it down as a separate formation on the geological map of Scotland; but he left the subject in a state of confusion which it will require much labour to clear up. The difficulty has arisen from relying exclusively on mineralogical definitions, and classing all rocks composed of certain mineral constituents as members of one formation, without regard to their origin or geological age. Thus a rock resulting from plutonic action upon stratified sandstone has been confounded with another which is geologically undistinguishable from gneiss, because they both consist of quartz and mica, quartz and felspar, or some other arbitrarily defined compound.

Although by no means in a position to class under their proper heads all the quartz-rocks of the Highlands, I trust that I shall be doing good service if I can determine correctly the geological position of part of them, and, by calling attention to the others, induce observers to examine those districts which I have not been able to visit, with the view to settling the age and origin of the various deposits of this rock.

Mr. Cunningham is the only author I have met with who has done anything to clear up the confusion in which MacCulloch left this subject. In his excellent "Geognostical Account of Sutherland†" he describes the quartz-rock of that county as so connected and alter-

* Vol. ii. p. 215.

† Journal of the Highland Society, No. 46, Sept. 1839.

nating with quartzose conglomerate and limestone, that they constitute together one deposit which he calls the "Quartz-series." This series is overlaid by red sandstone, and itself overlies the red sandstone of Assynt. Mr. Cunningham regards all the limestones of the west of Sutherland as belonging to the Quartz-series, and he states that the great mass of limestone of Assynt underlies the quartz-system of Ben More, and overlies that of Canisp*. From the remarks of this excellent observer, we may safely conclude that the quartz-rock and limestone of the west of Sutherland are part and parcel of the Old Red Sandstone Formation, with which it is thus intimately connected.

I have mentioned in my paper "On the Southern Border of the Highlands" (see p. 128) that the limestone of Aberfoyle is associated with beds of quartz-rock in the midst of a formation of red conglomerate which preserves its original character both above and below the metamorphic beds of quartz-rock. This is analogous on a small scale to the larger phænomena of Sutherland described by Mr. Cunningham. The explanation is easily found: the limestone acting as a flux assisted the reduction of the beds with which it was in contact, which were altered into quartz-rock, while the beds below, being less fusible, retained nearly their original characters, although, from being nearer to the source of heat, they were probably exposed to a higher temperature than the upper beds which we find altered. Similar superpositions of altered upon unaltered beds have been described by various authors, and the principle is now familiar to us.

To return to the north-west of Scotland. It will be seen in MacCulloch's map of Scotland that large masses of quartz-rock extend in a broken line from Sutherland down the west of Ross-shire into Skye, either separating the Old Red Sandstone from the Gneiss, or forming detached outliers on the Gneiss; and beds of limestone are marked in several places on that side of these masses of quartz-rock which is nearest to the Gneiss, that is to say, in the lower portion of them. Their position is so analogous to that of the quartz-rock of Sutherland, that we may, without danger, regard them as continuations of it, and class them in the Old Red Sandstone. I had an opportunity of confirming this view with regard to the hills of quartz-rock at the head of Loch Maree, which are part of the line in question. The lower part of these hills consists of a series of thin-bedded quartz-rock, separated by layers of micaceous schist, with a dip of S.E. 15°, and overlaid by a great thickness of semi-granular quartz-rock without mica, dipping S. 30°. The granular structure of the upper portion of quartz-rock shows it to have been originally a sandstone, since altered by plutonic action, and its position relatively to the Old Red Sandstone, at the foot and sides of the same lake, which is in many places partially altered into quartz, and which forms hills almost continuous with those of the quartz-rock, left me no doubt that the two belonged to the same formation. The lower portion of the quartz-rock admits of more doubt. It has no distinct granular character, and from its alternating with thin beds of micaceous schist cannot be

* *Op. cit.* pp. 92, 93, and 94.

distinguished from gneiss, to which formation I believe that it belongs. The want of conformity between the two portions makes this view more probable; but I leave the point doubtful, since I met with quartz-rock elsewhere of truly sedimentary origin, in which the beds were separated by thin beds of a micaceous schist.

I also examined several portions of the great deposit of quartz-rock which, reaching from Braemar to Blair Athol, forms an important part of the range of the Grampians. In the neighbourhood of Castleton Braemar, MacCulloch has laid down in the gneiss several patches of limestone nearly on the same line of strike as that of Glen Tilt, which is mapped as separating quartz-rock from granite. But the limestones of Castleton have in reality no connexion with the gneiss; they occur in the quartz-rock about 100 or 200 feet above its base. The lower members of the quartz-rock, consisting of beds of granular quartz, separated by thin beds of micaceous schist, have been mistaken for gneiss, to which they are quite unconformable; and the gneiss is represented as covering far too large a surface of the country. The contortions of the folia of gneiss, and their steeper inclination contrast with the regularity and comparative horizontality of the quartz-rock, making it easy to separate them; and the stratified structure of the limestone completes the evidence of the sedimentary nature of the formation of quartz-rock of which it is a part.

There are here between 20 and 30 feet of limestone, more or less mixed up with siliceous grains, and consisting of well-marked beds, divided by light and dark grey bands, parallel to the bedding. In the immediate neighbourhood of Castleton, the limestone and the beds of quartz-rock, with which it is associated, have been disturbed and broken up by the eruption of a mass of granite, on which the old castle of Mar stands; hence there appear to be several beds of limestone, which are, however, all parts of one bed. The same limestone is worked in Glen Ey, about two miles south of the junction of the Ey and the Conny, where it also occurs near the base of the quartz-rock. This locality lies nearly in a line between Castleton to Glen Tilt, and helps to connect together the limestones of those two places.

For well-known reasons I was unable to visit Glen Tilt, but I have no hesitation in classing the limestone of that Glen with the bed just described, since MacCulloch remarks that it is "interstratified with quartz-rock and with different varieties of schist *."

In ascending Glen Clunie from Castleton, we pass for some miles over quartz-rock, but about five miles higher up mica-schist appears in the bottom of the Glen, and the lower beds of the quartz-rock are again brought to view: here also limestone has been worked by the farmers in the lower part of the quartz-rock. On the southern edge of this great quartzose deposit in Glen Beg, an upper branch of Glen Shee, we find on the right side of the Glen a similar limestone a little above the base of the quartz-rock, but in a spot which MacCulloch has coloured as mica-schist.

The lowest part of the quartz-rock is well laid open in the beautiful

* "MacCulloch on Glen Tilt," Trans. Geol. Soc. vol. iii. p. 271.

chasm cut through it to the mica-schist by the waters of the Conny, a little above their junction with the Dee. There are here exposed above 200 feet of thin-bedded quartz-rock, regularly stratified, with a dip of 10° to the S., and alternating, towards the base, with thin beds of micaceous schist.

As all the masses of limestone above-mentioned have much the same character with well-marked stratification, and all occur in the lower members of the quartz-rock formation, we must class them together, and they would alone establish the stratified and sedimentary origin of the quartz-rock, which is confirmed by the granular structure of most of its beds indicating that it is an altered sandstone. It is exceedingly probable that most of the bands of limestone which figure in so strange a manner in MacCulloch's map among the gneiss and mica-schist of the southern part of the Highlands, will prove to belong to outlying masses of quartz-rock, which have been confounded with the crystalline rocks on which they rest.

I met with such an outlier of quartz-rock, accompanied with limestone, on the north side of Loch Earn, about a mile below the head of the lake. The limestone is worked in a large quarry visible from the road; it consists of many beds, of which the upper 50 feet are very siliceous, and about 20 feet are tolerably pure limestone of a grey colour and semicrystalline structure. Below it are about 100 feet of quartz-rock, resting unconformably on contorted mica-schist, and above the limestone is also quartz-rock which is overlaid by a great mass of trap. The partings both of the limestone and of the upper and lower portions of the quartz-rock are micaceous. The nearest spot to this in which quartz-rock is marked on the map is fifteen miles off to the north; but I expect that many other masses of the same formation will be found in this part of the country, as I heard of limestone-quarries in several places, whose occurrence I could only explain on such a supposition.

MacCulloch has laid down a band of quartz-rock, running between the mica-schist and the gneiss, from Glen Urchay, through Glen Lyon and Schiehallion, to Glen Tumel, of which I have only seen some portions. In Glen Urchay and about Tyndrum the rock is a quartzose variety of gneiss, with a foliation conformable to that of the neighbouring gneiss and mica-schist. I did not visit Glen Lyon, but from MacCulloch's remark that "the boundary of almost the whole of the northern side, as far at least as from Meggarney to Fortingall, consists of a sort of compact sandstone or granular quartz *," we may conclude that there are in that neighbourhood some deposits of sedimentary quartz-rock or metamorphosed sandstone. The upper part of Schiehallion has been described by Dr. Playfair as consisting of "pure quartz, granular quartz, quartzy sandstone with mica, indurated sandstone, grey sandstone, containing mica in thin layers," &c.†, which sufficiently indicate that this mass of quartz-rock is an altered sandstone, and does not belong to the mica-schist which forms the surrounding country. The occurrence of distinctly stratified lime-

* MacCulloch on Quartz-Rock, Geol. Trans. vol. ii. p. 469.

† Lithological Survey of Schiehallion, Phil. Trans. for 1810, pp. 352 and 358.

stone in several places round the mountain adds farther probability to this view, although the exact nature of the connexion between the quartz-rock and the limestone is not distinctly seen. Both Playfair and MacCulloch represent the stratification of the quartz-rock of Schiehallion as nearly vertical, and undoubtedly the principal divisional planes are nearly perpendicular, with a direction of W. 10° N.; but there is another set of divisions nearly horizontal, which, though less marked than the former, may represent the original stratification of the sandstone*. Nothing can be more fallacious than the view, suggested by the map, that the quartz-rock separates the gneiss from the mica-schist in this part of Scotland: the quartz-rock forms no such continuous band as is represented, and the gradual passage from gneiss into mica-schist may be seen in innumerable places.

There are several other important tracts of quartz-rock which I have not seen, and can only allude to slightly.

In the south of Caithness, the range of the Scarabins, "entirely composed," according to Professor Sedgwick and Sir R. I. Murchison, "of beautifully white compact quartz-rock," is encircled by old red sandstone†. This, therefore, without belonging to the Gneiss, seems to be of a formation anterior to the Old Red Sandstone.

A large part of Banffshire is formed of quartz-rock, which is laid down both on MacCulloch's map and on the more detailed map of that county by Mr. Cunningham‡. The great mass of quartz-rock on the coast near Cullen seems to belong to the Old Red Sandstone, with which it is continuous; but all the narrow strips of quartz-rock which occur in the schistose district of the county appear, from Mr. Cunningham's map and description, to be interlaced with the gneiss and mica-schist, and to have the divisional planes conformable to the foliation of those rocks: so that it must be presumed that they belong to the Gneiss.

MacCulloch has described at some length the quartz-rocks of Jura and Isla§: it would seem that there are in those islands quartz-rocks belonging to both the classes which I have been endeavouring to establish. The conglomerates with pebbles and fragments of quartz and jasper in Jura‖, and the conglomerates of Isla¶ are clearly sedimentary formations, with which the limestones of Isla are associated: on the other hand, the direction and dip assigned to the divisions of the great formations of quartz-rock through both islands agree sufficiently with that of the foliation of the gneiss and schists on the neighbouring land to make it probable that a large proportion of the quartz-rock is connected with that class of rocks.

It may be of some importance to point out to the agriculturists that the principal deposits of limestone throughout the Highlands lie

* Playfair says of these, "the rock is much cut by fissures transverse to its stratification." When I visited Schiehallion in 1849, being prepossessed with the notion that the rock was vertical, I omitted to note the dip of the transverse divisions, of which I have a distinct recollection.

† Trans. Geol. Soc. 2nd series, vol. iii. p. 128.

‡ Journal of the Highland Society, No. 57, for June 1842.

§ Western Isles, vol. ii. pp. 208, 239.

‖ *Loc. cit.* p. 210. ¶ *Loc. cit.* p. 250.

either at the base of the Old Red Sandstone or at the base of the Quartz-rock; since this indication will materially assist them in their search for this useful rock. Every calcareous deposit *of any importance* which I visited belonged to one or other of those positions. Some of the limestones of Banffshire may perhaps be exceptions, as are also the limestones of the Oolites and Lias on some parts of the coast. But, throughout the greater part of the Highlands, the only limestone beds really worth working occur a little above the base of the Old Red Sandstone and Quartz-rock, and these, like the calcareous beds of the Old Red Sandstone elsewhere, are not continuous, but occur here and there at about the same geological level.

There are also some very insignificant masses of limestone in the Gneiss and Mica-schist, but these are rare and of little value. The limestone occurs, as one of the constituents of the foliated rock, in sheets, rarely exceeding six inches in thickness, which are conformable to the folia of quartz, mica, &c., of which the rock may be composed, and exhibit no internal traces of stratification. In a country where limestone is so rare, it may be desirable to map these deposits on economical grounds; but geologically they have no more claim to figure separately on our maps than have the quartz, mica, or felspar which occur with them. An instance of limestone occurring in this manner in mica-schist may be seen near Lawers, on the north side of Loch Tay; and in gneiss, in several spots on the north side of Loch Maree in Ross-shire, especially in the hill behind Letter Ew; and other instances are probably to be found elsewhere*.

I have endeavoured to show in the preceding remarks that the quartz-rock of the Highlands must be divided between two most distinct classes of rocks:—

1st. A foliated rock, allied to gneiss, with which it may be classified without requiring a separate colour on our maps, or a distinct name in our nomenclature.

2nd. A stratified rock of sedimentary origin, altered from sandstone into more or less homogeneous quartz-rock by plutonic action, as in the now well-understood cases of the Stiper Stones and the Lickey.

In considering to what formation of sandstone we are to refer the metamorphic quartz-rocks, we must recollect that as yet we know of no sandstone in any part of the Highlands older than the Old Red Sandstone; that this formation is more than equal in thickness to the quartz-rock, and that the more modern sandstones play an insignificant part in those districts, having only been observed at a few places on the coast. It seems, therefore, reasonable to refer the whole of the Quartz-rock to the Old Red Sandstone, especially as the quartz-rock of Sutherland and Ross-shire undoubtedly belongs to that formation, and the similarity of character and the frequent occurrence of limestone in the same part of the series are strong arguments for connecting all the stratified quartz-rocks together. The change in

* I must warn the traveller in the Highlands that the publisher of MacCulloch's Map has most unfortunately chosen almost the same tints for "primary limestone" and "trap-rocks and porphyry," so that, when in search of a supposed band of limestone, he will sometimes come upon a trap-dyke.

character between the lower beds of quartz-rock, alternating with micaceous schist, and the upper part, which is almost exclusively siliceous, corresponds with what we should expect to find in a crystallized Old Red Sandstone, of which the lower division is composed in part of argillaceous beds fit to furnish the micaceous schist, and the next division contains very little clay.

The masses of quartz-rock which harmonize least with this arrangement are those of Schiehallion, Ben Gloe, and the Scarabins; if we leave these in suspense, and only admit that the rest of the stratified quartz-rocks belong to the Old Red Sandstone, it will still follow, from the position of the various masses described, that that formation must have covered the southern portions of the Highlands at least as far up as the Grampians.

February 4, 1852.

The Rev. J. Gunn was elected a Fellow.

The following communications were read:—

1. *On the* Southern Border *of the* Highlands *of* Scotland. By D. Sharpe, Esq., F.R.S., V.P.G.S.

Having lately visited many of the passes leading into the Highlands, I found the arrangement of the rocks along the border so different from what I had been led to expect by what has been published on the subject, that I venture to offer the following remarks upon the Border formations, although I am far from having materials for a complete account of them.

Mr. Nicol's 'Guide to the Geology of Scotland' gives us a good summary of what was known on the subject up to 1844, and little or nothing has been added since; his account, therefore, will often be referred to.

In MacCulloch's Map of Scotland a band of blue colour, indicating "Clay-slate or Greywacke," stretches across Scotland from Stonehaven to Bute and Arran, bounded on the south by the Old Red Sandstone, and on the north by mica schist, and within this clay-slate are represented the bands of limestone of Loch Lomond and Aberfoyle. Mr. Nicol's map includes in the same band of clay-slate the limestones of Callander and that on the South Esk near Cortachie. Mr. Buist's Map of Perthshire, published in the forty-fifth number of the Journal of the Highland Society, draws into the same Clay-slate Formation the limestone between Dunkeld and Blair Gowrie. These views are at least consistent, for there can be little doubt that all these limestones are contemporaneous; but, from the visits I made to several of the quarries, I have no hesitation in referring them all to the Old Red Sandstone. Mr. Buist goes still farther in favour of the clay-slate, carrying it up five or six miles north of its real boundary to include in it some outlying patches of limestone marked by MacCulloch, and thus colours as clay-slate a large

extent of micaceous schist. Thus there has been a sort of conspiracy to give an undue importance to the Clay-Slate, which has got mapped of nearly double its real width; and which, as far as I could learn, contains no subordinate beds of limestone.

In the eastern part of its course, the band of clay-slate belongs to a single formation, being a dark grey or dark blue slate, of nearly uniform character, the finer beds of which are worked in many places for roofing slate: but to the westward there are two formations of slate, whose mineral characters are sufficiently different to make it desirable to distinguish them. The lower of these two is the dark bluish grey slate just mentioned, over which lies a series of beds of great thickness of a light green or greenish grey chloritic slate, containing beds of slaty conglomerates of a similar green colour, full of small pebbles of white quartz, which are here and there so abundant as almost to deprive the rock of its slaty character. With these few exceptions, both the bedding and the cleavage of the slates of both series are well marked throughout their course.

We cannot decide the age of these slates until organic remains have been found in them; but, in the absence of such conclusive proof, we must fall back on the best evidence we can obtain, which is that of mineral character: this leads me to compare them to the two great Slate Formations of Westmoreland and Cumberland, long since distinguished by Professor Sedgwick, viz. the green slate, chloritic, quartzose, and often brecciated, overlying the dark clay-slate of Skiddaw.

The position of these slates differs so much in various parts of their course, as to make it necessary to describe in detail the sections visited; in doing which I will commence at the east where their arrangement is least complicated.

Fig. 1.—*Section from the Brig-o-Cally, in Glen Shea, to Blair Gowrie.*

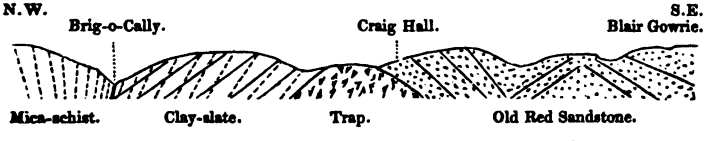

Figure 1 is a section from the Brig-o-Cally in Glen Shea to Blair Gowrie. The clay-slate dips at an angle of about 30° towards the mica-schist, being obviously thrown into that position by a great dyke of greenstone trap which separates it from the Old Red Sandstone. The actual boundary between the schist and slate was not seen: the band of slate is about three miles wide. It has been quarried for roofing slate about one mile below the Brig-o-Cally. The Old Red Sandstone, in the picturesque gorge below Craig Hall, is a coarse breccia containing large boulders of quartz, jasper, &c., in a matrix which has been altered by the influence of the neighbouring trap into a crystalline mass. Half a mile lower down the river, the conglomerate is found unaltered, and thus it continues to Blair Gowrie.

I could not find the limestone which, in Mr. Buist's map, is placed at Rattray; but the spot where he has marked it is in the Old Red Sandstone. I had not time to visit the limestone between Blair Gowrie and Cluny, but the strike of the beds in the neighbourhood left me little doubt of their lying in the Old Red Sandstone. The position of the clay-slate on the Tay is so nearly the same as that just described, as not to require a figure. It covers a breadth of about four miles from Dunkeld to Birnan Hill, at which latter spot it is largely quarried, and supplies an excellent roofing-slate. The beds dip N.W. towards the mica-schist at about 60°, and they meet the Old Red Sandstone without any trap appearing between them; yet the trap-dyke probably runs below the surface, and has produced the apparent anomaly of clay-slate dipping N.W., meeting, on its southern edge, Old Red Sandstone dipping S.E., the two thus appearing to form an anticlinal axis.

The next valley to be mentioned is Strath Earn; but the abundance of drift in the valley prevented me from getting a complete section. The clay-slate is not two miles wide, and is very highly inclined; on the north side of Comrie, where it meets the mica-schist, it dips N. 85°.

Thus far we have only met with the lower formation of dark clay-slate; but in the sections to the westward, which are next to be described, the upper green slate comes also into view.

Fig. 2.—*Section of the Valley between Aberfoyle and Loch Chon.*

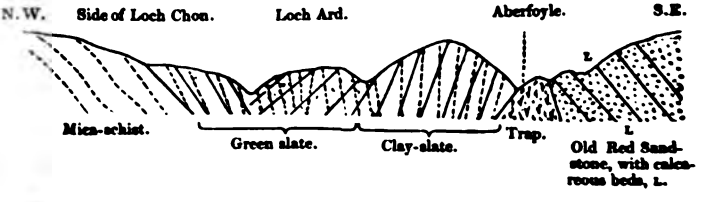

Fig. 2 is a section of the beds seen in the valley between Aberfoyle and Loch Chon. The Old Red Sandstone is separated from the clay-slate by a great dyke of greenstone-trap ¼ of a mile wide, on which the Inn of Aberfoyle stands, and which crosses the valley and enters the hills on both sides, running about E. 20° N. The lowest part of Old Red Sandstone is a dark brown grit, perhaps between 200 and 300 feet thick; on this rests a bed of limestone, marked L L in the section, associated with thick beds of quartz-rock with partings of steatite, surmounted by a great thickness of coarse ferruginous conglomerate many hundred feet thick, with pebbles larger than cannon-balls. All the beds of the Old Red Sandstone dip about S. 20 E. 40°. Owing to the upper part of the quarry having lately fallen in, I was unable to see the thickness of the calcareous beds.

The north side of the trap is overlaid by the dark clay-slate, dipping N. 20 W. 80°., which forms a band a mile and a half wide, on the northern side of which is a large quarry of excellent roofing-

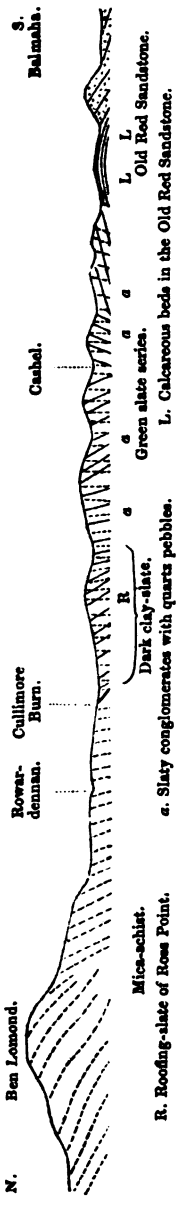

Fig. 3.—*Section along the East side of Loch Lomond.*

slate. This is overlaid to the northward by the chloritic or "green slate," which dips N. 20° W. 65°, where it overlies the clay-slate, but at the side of Loch Dow is suddenly turned up with a dip of S. 20° E. 50° to 70°, and farther north, on the side of Loch Chon, rests immediately on mica-schist. Some of the beds of green slate are full of small quartz-pebbles.

To the eastward of this section the green slate is well seen in the Trossachs, and also between Callander and Loch Lubnaig, on both which sections it covers a breadth of three or four miles. The beds of slaty quartzose conglomerate are of great thickness, and pass downwards on its southern edge into a coarse slaty greywacke, which may be seen both at the head of Loch Vennachar and at the falls of the Leny, resting on greenstone-trap, which bounds the slates southwards. According to Mr. Nicol*, the clay-slate runs through both Ben Ledi and Ben Venue, where it must come up between the green slate and the mica-schist.

To the westward of Loch Chon the green slate is interrupted by the upheaval of the mica-schist of Ben Lomond, which throws the band of slates several miles south of the course it follows to the eastward; but the dark clay-slate continues from near Aberfoyle to the Ross point on the west side of Loch Lomond, where it dips S. 20° E. 65°, and rests on the mica-schist, being overlaid farther south by the green slate, as is seen in fig. 3.

The section of the east side of Loch Lomond (fig. 3) is very clear and instructive. From the head of the lake to the Cullimore Burn, ¾ of a mile below Rowardennan, the side of the lake (including Ben Lomond) is formed of mica-schist: this is overlaid by clay-slate, forming a band about a mile wide, and dipping S. 20° E. 65° to 70°. This is overlaid on the south by the green slate, which covers about four miles of the side of the lake, and is arranged in a great synclinal axis, as on the Aberfoyle section; but, instead of our finding the clay-slate rising from below the southern edge of the green slate, as at Aberfoyle, the green slate meets the Old Red Sandstone about ¾ of a mile north of Balmaha. The lower part of this green slate series, which is thrown up both at its northern and southern edge, includes

* *Loc. cit.* p. 149.

thick beds of slaty conglomerate, full of small quartz-pebbles. The lowest member of the Old Red Sandstone consists of coarse ferruginous sandstone, alternating with red marls, and containing some very irregular beds of little thickness of nodular limestone mixed with steatite, which have been worked by the side of the lake above Balmaha. This set of beds forms a low arch dipping to the south under a great thickness of coarse red conglomerate, and dipping also towards the slate on the north, which has, no doubt, led to the limestone it contains being erroneously mapped as part of the slate series. The coarse conglomerate rises into a high ridge of hills, which terminates at Balmaha. A similar ridge, formed of the same member of the Old Red Sandstone, is a prominent feature a little to the south of the slates, along a great part of the Highland Border; it is everywhere remarkable for the large size of its pebbles, often a foot in diameter, which distinguish it from the beds both above and below it. Near Balmaha this conglomerate dips E. 40°, S. 40°, and contains another bed of limestone worked on the north face of the ridge. The conglomerate is overlaid on the south by a red sandstone, dipping at first 30°, and becoming more nearly horizontal to the southward.

The limestone of Auchmar lies also in the lowest member of the Old Red Sandstone, between beds of red sandstone and variegated marl, overlaid by the coarse conglomerate. The bed of limestone varies in thickness, nowhere exceeding 7 feet; it is nodular and mixed up with marl. Only the extreme rarity of lime in the Highlands could cause so poor a bed to be worked.

On the west side of Loch Lomond the clay-slate is quarried at Luss, where it rises between two great bands of trap. The green slate occurs on the north of the clay-slate, and rests on the mica-schist; here, as at Aberfoyle, overlapping and concealing the northern edge of the dark clay-slate. Judging from MacCulloch's descriptions, both the formations of slate are continued to the westward along the north of the Firth of Clyde.

At the first glance the positions of the slate in the sections just described are perplexing, and appear contradictory. To account for them, we must suppose that the trap-rock, which breaks through in several places, is continued below the surface, and runs along the whole line of the Highland Border. In some parts of its course it has raised up the whole mass of the slate, until it all dips to the north towards the mica-schists. In other parts, only the southern half of the slate-series is so raised up by the trap, and the northern portion dips southward, and rests in a less disturbed position on the mica-schist. The manner in which the clay-slate is brought up alternately on the north and south side of the green slate is very remarkable, and can only be explained on the supposition that it is concealed in some places by an overlap of the newer deposit of green slate.

From Aberfoyle eastward the band of slate-rocks follows a nearly regular course of about E. 30° N., with a slight deflection near Strath Earn; but to the west of Aberfoyle its course is less regular, being successively thrown to the south in a series of breaks: the most important of these is connected with the elevation of Ben Lomond, where

the mica-schist reaches about four miles to the south of its boundary westward, thus bringing the mica-schists of Ben Lomond on the line of the green slate of Loch Chon*. I presume that to this is owing Sir R. Murchison's allusion to the "pebble-beds in the chlorite schist of Ben Lomond†." The beds so mentioned are obviously those slaty conglomerates with quartz-pebbles which I have just described as forming part of the chloritic or green slate series, which reach the western flank of Ben Lomond, but cannot be considered as forming part of that hill. I ascended Ben Lomond from Rowardennan, passing all the way over mica-schist, and MacCulloch expressly states that the whole mountain consists of micaceous schist‡.

The chloritic or green slate is a truly stratified sedimentary formation, in which the bedding is distinctly seen to be traversed by the planes of slaty cleavage. Moreover, it is not the lowest of the sedimentary formations of the district; it is therefore important that it should not be confounded or coupled with the mica-schist of Ben Lomond, a foliated rock of crystalline origin, in which there is only one set of divisional surfaces, namely those of foliation. The distinction between these two classes of rocks—the stratified slates traversed by cleavage, and the foliated schists without any second set of divisional planes—is one of the most important in geology, and cannot be overlooked without leading to hopeless confusion.

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2. *On the* Discovery *of* Gold *in* Australia.

By the Rev. W. B. Clarke, M.A., F.G.S.

[Abstract.]

In April 1841, Mr. Clarke undertook his first journey of exploration from the east coast of Australia to the westward, in the parallel of Port Jackson. On that occasion he became first acquainted with the geological position of the Carboniferous series of New South Wales with respect to the older rocks composing the axis and western flank of the great chain called the Blue Mountains, which also, in consequence of their extension N. and S. through many degrees of latitude, have been appropriately denominated "the Australian Cordillera."

Although, on the occasion alluded to, says the author, my observations were made without much precision, I nevertheless became aware that the axis consisted of elevated schists of various kinds parallel with the meridian, together with some limestones, and that granitic rocks of a younger epoch had intruded into them, and were accompanied by dykes of quartz. The presence also of greenstones, diorites, syenites, porphyries, basalt, and other igneous products was

* Since the above was written, Mr. Pratt has informed me that a considerable mass of porphyry rises through the mica-schist a little to the north of Inversnaid. Probably the disturbance mentioned in the text is caused by the eruption of the porphyry.—[March 23, 1852.]

† Quart. Journ. Geol. Soc., vol. vii. p. 169.

‡ Trans. Geol. Soc. vol. ii. p. 446, note.

also detected. There was evidence also of the schists having undergone various transmuting influences, and of the granites having suffered from causes which had in places produced disintegration. The Carboniferous formation was exhibited as resting upon the older rocks, either reposing unconformably upon the tilted schists or granites, or passing into the ancient conglomerates derived from the latter*. I discovered at that time the presence of gold, both in quartzites, and in the detrital accumulations derived from the axial formations; but it was only sufficient to enable me to declare that gold existed within eighty and sixty miles of Sydney.

By subsequent researches, the author's acquaintance with the geology of the country was considerably extended, and he was led to regard Australia as an auriferous region of considerable promise,—an opinion which he has promulgated in several of the local journals; and ultimately he was convinced (as expressed in a letter, a quotation from which appeared in the 'Quarterly Review' for September 1850) that copper, lead, and gold are to be found in considerable abundance in the schists and quartzites of the Cordillera (Blue Mountains). Under these terms are included all the alternations of the schistose formation which occur between 27° and 38° lat.; that portion, however, being chiefly alluded to that lies between the Liverpool Range and Wilson's Promontory. Having had ocular proof that gold actually existed in many places within an area represented by 9° of latitude and 4° of longitude, the author felt justified in extending his assertion with respect to the presence of gold in Australia, so as to embrace the further extent of country throughout which rocks of a similar kind extend. After dwelling on the similarity of the geognostical characters of the Australian and the Ural Ranges,—his views on which were published in 1847†,—and on the meridional parallelism, at the respective distances of exactly 90°, that obtains apparently amongst what he considers to be the several great auriferous mountain-ranges of the world, Mr. Clarke proceeds to observe, that the most recent intelligences enable him to state that the actual length of the auriferous quartz ranges is full sixty miles, if not more, reckoning from Summer Hill, which is the range separating the waters of the Bolubula, an affluent of the Lachlan, from the basin of the Macquarie, in which the gold-diggers are now employed. Summer Hill is not more than ten miles east of the summit of the Canobolas, a cluster of basaltic and porphyritic hills, which have burst through the schists, and have transmuted also the overlying fossiliferous limestones. Taking the width of the auriferous region in this part of the basin of the Macquarie at twelve miles, we have here an area of at least 720

* For an account of the Palæozoic Rocks of New South Wales, see Quart. Journ. Geol. Soc. vol. iii. p. 241 *et seq.*, and vol. iv. p. 60 *et seq.* Also Strzelecki's Physical Description of N. S. Wales and Van Diemen's Land, p. 87 *et seq.*, and Jukes' Physical Structure of Australia, p. 11, and p. 18 *et seq.*

† A comparison of the phænomena of the Ural with those of Australia (which Mr. Clarke was enabled to institute by means of an Abstract of M. de Verneuil's Report to the Geological Society of France, on the Researches in Russia by Sir R. I. Murchison, Count A. Keyserling, and himself) was published in the Sydney Herald, Sept. 28, 1847.

square miles,—in a great part of which, either in the rock *in situ*, or in the detritus, gold is found in more or less abundance.

In 1851 gold was discovered in Summer Hill Creek and along Lewis' Ponds*, a N. and S. affluent of the Macquarie, more than thirty-five miles distant from Bathurst. Gold has also been detected within a few miles of Bathurst, and on the west of the Summer Hill range, in the cupriferous region of Carcoor and Coombing; and most probably as prolific a field exists south of that district as to the north of it.

The country in the immediate vicinity of the gold-diggings consists of schist, traversed by quartz-dykes, vertically bedded, and fissured by deep creeks. Where the points of junction with minor creeks occur, bars of schist serve to accumulate the fluviatile and more ancient drift, and it is there especially that the gold is accumulated. Masses of from one to four pounds weight have been found, together with smaller pieces, in the interstices of the schist, which is covered by clay and detritus.

In the banks of the creeks and on the plains, such as Pretty Plains, King's Plains, &c., gold also occurs. The trend of the creeks, as well as the ranges, is to the north and south, and this kind of country continues for at least 100 miles. The dip where the "diggings" now are is at a high angle to the N.E. At some points, as near the junction of Meroo Creek and the Cudgegong River, and thence by Gouraba to Wonderry, the quartz is studded with beautiful nests of gold, very abundant and easily detached by the blow of a hammer.

As Oakey Creek, south of the Canobolas, and others falling into the Bolubula and Abercrombie also contain gold, there can be no doubt that abundance will be also found in other affluents of the Lachlan. Nor is the discovery confined to this immediate region, for it has been detected at various points along the whole line of quartz-rock and slate ranging between the meridians of 149° and 148° E., as far as the valleys radiating from Mount Kosciusko. The whole basin of the Macquarie River, and various points on the Manning, Clarence, and Mac Leay Rivers to the northward are rich in gold. The quality of the gold is good. It is purer in colour than the Californian metal, being alloyed with a less proportion of silver; some small specimens have given on analysis $7\frac{1}{2}$ grains of pure gold out of a lump of quartz-ore weighing 17 grains.

The mineral structure and geological composition of Tasmania being phænomena continuous from those of Australia, it is highly probable that gold will be detected, if search be made, at the head of King's River and below the range running from Mount Humboldt to Western Bluff.

The question of the prolificness of the Australian gold-field in the basin of the Macquarie having been set at rest by the abundance of the metal already discovered, and the extent being, in all probability,

* The amount of gold taken from Summer Hill and Lewis' Ponds Creeks is said to be worth about £5000 sterling; and this was obtained in little more than three weeks' time. But there is reason to believe that from the alluvium of these Creeks there will not be a much further supply.

conterminous with that of the associated schists and quartzites, it may be safely concluded that Australia will be found one of the richest gold-bearing regions on the face of the globe.

Fuller details, observes Mr. Clarke, will be found in my forthcoming Report on the Geology of Australasia; nevertheless I have thought it advisable to give this brief account of one of the most valuable discoveries, of commercial importance, yet made in a British territory, and the final consequences of which will be of the greatest importance to the destinies of the Southern hemisphere.

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3. *On the* ANTICIPATION *of the* DISCOVERY *of* GOLD *in* AUSTRALIA; *with a* GENERAL VIEW *of the* CONDITIONS *under which that* METAL *is* DISTRIBUTED. By Sir RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. G.S., Pres. R. Geogr. Soc. &c.

[Abstract.]

THIS memoir is chiefly a *résumé* of the author's views on the distribution of gold in various parts of the world, as published during the last eleven years. This recapitulation is deemed requisite because the Rev. W. B. Clarke published in the Sydney Herald, May 29, 1851, a long article on Australian gold (reprinted in the English newspapers and in blue-books for the use of both Houses of Parliament), in which no mention is made of Sir Roderick Murchison's writings relating to Australian gold, although they were published between the years 1844 and 1850. In fact, the chief illustrations in the above-noticed article of Mr. Clarke had been printed in the work 'Russia and the Ural Mountains,' in the Journal of the Royal Geographical Society, in the Transactions of the Royal Geological Society of Cornwall, and of the British Association, and in the Notice of Discourse at the Royal Institution, &c.

From 1841 to 1843 Sir Roderick published descriptions of the auriferous phænomena of the Ural Mountains on different occasions, as read before the Geological Society and the British Association. In 1844 he compared the eastern chain of Australia*, about to be described by Strzelecki, with the Ural Mountains. In 1846 (a year before the Californian discovery) he addressed Sir C. Lemon, the President of the Royal Geological Society of Cornwall, on the subject, and recommended any Cornish tin-miners, who were unemployed, to emigrate to New South Wales, and dig for gold in the débris and drift in the flanks of what he had previously termed the "Australian Cordillera," in which he had recently heard that gold had been discovered in small quantities, and in which, from similarity with the Ural Mountains, he anticipated that it would be certainly found in abundance †. Having received letters from residents in Sydney and Adelaide, saying that, in consequence of his writings, they had sought and obtained

* Trans. Royal Geogr. Soc. vol. xiv. p. xcix. *et seq.*

† Trans. Royal Geol. Soc. Cornwall, 1846, vol. vi. p. 324 *et seq.* Also the Penzance newspapers of Oct. 1846.

gold, specimens of which they sent, the author wrote to Earl Grey, Minister for the Colonies, in November 1848, referring to his anticipation as being about to be realized in a manner which might operate a great change in the colony. From that time until the practical establishment of the view on an extensive scale by Mr. Hargreaves in 1851, he developed the Australian phænomena before the British Association and the Royal Institution; and, finally, he embodied his views in the article entitled "Siberia and California," in the 'Quarterly Review,' 1850.

Having next alluded to the diagrams illustrative of the subject which he had exhibited, and to the useful new maps of the gold-districts by Mr. Wyld*, the author spoke of a geological discovery recently communicated to him by the Rev. W. B. Clarke, F.G.S., viz. the existence of many fossils of known Silurian species, including *Pentamerus Knightii*, and many shells and corals, on the flanks of the dividing range of New South Wales. This discovery is important, for it completes the resemblance of the Australian Cordillera (along which Devonian and Carboniferous fossils had been found) with the Ural Mountains; the two chains being thus shown to be zoologically, as well as lithologically, similar, and both to possess the same auriferous "constants†." Such constants occur in many countries and have recently been found to obtain in the prolongation of the Apalachian chain into Canada, specimens of gold from whence were exhibited by Mr. W. E. Logan, F.G.S.

Sir Roderick entirely dissented from a theory propounded by Mr. Clarke,—that the production of gold in certain *meridional bands* of rock in both hemispheres has any fixed relation to four equidistant meridians; inasmuch as the exploration of Northern Asia or Siberia has shown, that the greater proportion of Russian gold-ore is not derived from the Ural, but from numerous other similarly constituted ridges, which occur at intervals throughout 70° or 80° of longitude.

The author concluded by recapitulating the data which he had been enunciating for some years respecting the distribution of gold‡, dwelling particularly on the *facts* which the labours of mankind had established, that auriferous vein-stones in the parent rock had been usually found to deteriorate in produce when followed downwards; and that their originally richest portions having occurred in the upper parts of the rocks, the most prolific gold-fields were composed of the débris or drift, which in former ages had been abstracted from the mountain-tops and distributed in gravel-heaps on their sides.

The author having further shown, that gold could only be abundantly found along the *back-bones* or most ancient parts of the land (more particularly in those countries which like Australia had never been inhabited by civilized men), and had never been discovered in any appreciable quantity in secondary or tertiary strata, it followed

* Notes on the Distribution of Gold throughout the World. 8vo. London, 1852.

† See Discourse at the Royal Institution in March, 1850.

‡ See Trans. R. Geogr. Soc. vol. xiv. p. lxiii. *et seq.*; and Athenæum Journal, Nos. 920, 1143, 1167.

that the gold-fields of nature, however rich along certain zones, were necessarily limited by such conditions.

Note.—Having above given the date of the publication in which I compared the "Australian Cordillera," then so named by me (1844), with the Ural Mountains, and that of my invitation to the Cornish miners to work for gold in that Cordillera (1846), I beg to state that English geologists are unacquainted with any other printed documents relating to Australian gold, *excepting my own*, anterior to a notice, by Mr. Clarke, of September 1847, in the Sydney Herald. That comparison of his of Australia with the Ural was, it will be observed, *three years and four months after* my publication on the same topic. His letter to me, an extract from which I gave in the Quarterly Review of September 1850, was long subsequent to his notice of 1847.—[R.I.M.]

February 25, 1852.

The following communication was read:—

On the Classification *and* Nomenclature *of the* Lower Palæozoic Rocks *of* England *and* Wales. By the Rev. Prof. Sedgwick, A.M., F.R.S., G.S.

§ 1. *Cumbrian Series.*

In a former paper*, of which this is a continuation, I endeavoured to ascertain the geological place of some groups of slate-rocks which are seen in certain parts of Westmoreland and Yorkshire near the base of the carboniferous limestone; and I endeavoured to show that the several groups which appeared on one or more of the sections were the equivalents, respectively, of the *Coniston limestone*, the *Coniston flagstone*, the *Coniston grits*, and the *Ireleth slates*, &c. These equivalents are well known, having been described by myself in former published papers†. But a new question may arise respecting their true place in the lower divisions of the whole palæozoic system. In the Cumbrian cluster of mountains, the whole series of deposits below the Old Red Sandstone has been long separated into three great physical subdivisions; the lowest of which included the Skiddaw slate; the middle was represented by a vast development of green slate and porphyry; while the highest included all the rocks of Westmoreland and Lancashire, from the calcareous slates of Coniston to the highest beds that were overlaid by the old red conglomerates, or were covered by the beds of the great Scar-limestone. Such were Mr. J. Otley's three physical groups; and they were adopted as the basis of classification by myself and others who followed him.

So soon as I became acquainted (in 1831 and 1832) with the rocks

* Quart. Journ. Geol. Soc. vol. viii. pp. 35–54.

† See papers, Proc. Geol. Soc. vol. i. p. 399 (*Cumbria*); *ibid.* vol. ii. p. 675 (*Cumbria and N. Wales*); *ibid.* vol. iii. p. 541 (*Cumbria and N. Wales*); *ibid.* vol. iv. p. 212 (*N. Wales*); *ibid.* p. 251 (*N. Wales*); *ibid.* p. 576 (*N. Wales and Cumbria*); Quart. Journ. Geol. Soc. vol. i. p. 5 (*Cumbria*); *ibid.* p. 442 (*N. Wales and Cumbria*); *ibid.* vol. ii. p. 106 (*Cumbria*); *ibid.* vol. iii. p. 133 (*N. Wales and Cumbria*); *ibid.* vol. iv. p. 216 (*Cumbria*).

of the upper and lower Cambrian series*, I hesitated not to identify the Coniston with the Bala limestone; and in a short published scheme† I endeavoured to bring all the rocks, from the Coniston limestone to the Ireleth slates inclusive, into a provisional comparison with my upper Cambrian groups; viz. those groups which, at the south end of the Berwyn chain, are superior to the Bala limestone; and are thence sent off, in great undulations, and form the physical groups of a considerable portion of South Wales. This scheme I now believe to have been very nearly right; and it would have been perfectly right had I not included the Ireleth slates among the equivalents of the so-called upper Cambrian system‡.

During a subsequent year (1841), on my return from Scotland, I paid a very short visit to some of the Westmoreland quarries. Nearly all my old collections (the accumulations of more than twenty years) were at that time inaccessible to myself; but having procured some good Coniston fossils, and having received, from my friend Mr. James Marshall, a still better series, they were carefully examined; and, almost species by species, they agreed with the Silurian fossil lists of the Caradoc sandstone. Nor was this all the evidence on which I then modified my first classification§. The Coniston limestone and calcareous slates appear to pass into the Coniston flagstone by almost insensible gradations; and the flagstone contains *Graptolites* which I referred (perhaps erroneously) to the species *Ludensis*; and in many different places it contains whole beds of *Cardiola interrupta*, and a few other species, which are among the characteristic lists of the upper Silurian rocks. This evidence appeared at that time to be irresistible; and I so far modified my first attempt, that I no longer brought the Coniston and Bala limestones into immediate comparison, but considered the Coniston limestone as the exact equivalent of the Caradoc sandstone. *On this hypothesis* the whole series of rocks (Mr. J. Otley's third great physical subdivision), from the Coniston limestone upwards, formed the *exact equivalents* of Sir R. I. Murchison's Silurian groups, from the Caradoc sandstone to the upper Ludlow rocks inclusive.

I need not detain the Society by any further reference to papers, abstracts of which were published during former years; but it was obvious, from the first, that the Coniston limestone was a bad *physical equivalent* of the Caradoc sandstone; and, on the scheme here

* By Cambrian series was understood the whole great undulating series between the Menai and the edge of Shropshire. Lower Cambrian on my first scheme included all the rocks west of the Bala limestone. Upper Cambrian included the Bala limestone and all the slate-rocks above it. In the present paper the Upper Cambrian series (or great Bala group) is made to commence at a considerably lower level; viz. with the black slates immediately on the east side of the porphyritic beds of the Great Arenig. In this way we avoid an ambiguity arising from the difficulty of tracing the exact equivalent of the Bala limestone through South Wales; and the great undulating system south of Cader Idris and east of Cardigan Bay becomes at once comprehended in the Upper Cambrian series.

† Proceedings Geol. Soc. vol. ii. p. 678.

‡ It appears that the Ireleth slates are very nearly the equivalents of the Wenlock shale.

§ Proceedings Geol. Soc. vol. iii. p. 551.

alluded to, the Coniston grits had *no physical representative* among the typical upper Silurian groups. I ascertained, moreover, in the year 1845, that the Coniston limestone, at its south-western extremity, was actually so interlaced with the green slates and porphyries of the great central system of the Cumbrian mountains, that it could not, at least on physical evidence, be separated from them. Hence I gradually came back nearly to my first interpretation of the phænomena.

The Coniston limestone I again considered as a true Cambrian rock, and the equivalent of the Bala limestone; and its fossils have within the last three or four years been arranged by Professor M'Coy in conformity with this view. But the Cardiola-flags still presented a great difficulty, as I had never seen the *Cardiolæ* but among rocks supposed to be upper Silurian: and, if possible, to clear away this difficulty was one of my objects in my visit, during the past summer, to the flagstones near Horton in Ribblesdale.

On writing to Professor M'Coy on the propriety of classifying the Coniston flags with the upper Bala group, and the Coniston grits with the Caradoc sandstone, I had a reply in which he used the following words:—"I by no means think that we have yet fossil evidence enough for *determining zoologically* the age of the flags and grits in question; nor the age of similar beds in a few other localities which in our MS. lists stand as doubtful; and I am glad you are collecting more evidence. Meanwhile your field-impressions, I have little doubt, will prove correct." At the same time I may remark, that neither he nor I had a shadow of doubt that the Coniston limestone was the equivalent of the Bala; and this conclusion necessarily influenced our opinion respecting the age of the Coniston flags and Coniston grits. If the Coniston limestone and flagstone *could* be brought to the parallel of the upper Bala groups, it followed almost of necessity that the Coniston grits, geologically and physically, must be the exact equivalents of the Caradoc sandstone; and thus would a great physical difficulty be removed; and the Westmoreland series would agree, stage by stage, with the successive groups in North Wales, and with the successive stages of the Silurian rocks, as they had been made out by the author of the 'Silurian System.'

Knowing the importance of these determinations, I engaged, during last autumn, my friend John Ruthven to re-examine, at his leisure, all the fossil-bearing quarries in the Coniston grits and flags; and I hope, before long, to receive from him such a series of fossils as will settle the zoological evidence bearing on the exact age of the two last-mentioned groups, and put an end to any remnant of doubt as to that essential point.

About five weeks after my return to Cambridge I received (Nov. 6, 1851), unexpectedly and to my great pleasure, a note from Mr. Salter (on whose authority the lists of Westmoreland fossils given in my previous papers, in 1845–1846, had been made out*), containing the following critical remarks:—"In your most complete list of

* See also 'Letters on the Geology of the Lake District.' Hudson, Kendal, 1842.

fossils from the Coniston (or Brathay) flags I find the following:—1. *Cardiola*. 2. *Creseis* (*Orthoceras*). 3. Large *Orthoceratites*. 4. *Graptolites Ludensis* (now *G. priodon*). 5. *Astræa ananas*. 6. *Asaphus* (*Phacops*) *caudatus*. 7. *Atrypa compressa*." I may remark, that when this list was examined and determined, these flags were regarded as upper Silurian, and nearly on the parallel of the Wenlock shale. "Let us now (adds Mr. Salter) examine these fossils with a view of putting them in the upper Bala groups. I should not now call them upper Silurian.... For *Cardiola* (1.) occurs in Llandeilo flags at Builth; *Creseis* (*Orthoceras*) (2.) is plentiful in Llandeilo flags; large *Orthoceratites* (3.), species not named, prove nothing, and large smooth species, from what we know of the Scotch series, are quite as characteristic of older rocks; *Graptolites priodon* (4.) is known to be plentiful in Llandeilo flags; *Astræa ananas* (5.) is also found in Coniston limestone; *Phacops obtusicaudatus* (6.) is described, in my appendix to your second Fasciculus of the 'Cambridge Palæozoic Fossils' (now in the press), as a perfectly distinct species, allied to *Phacops caudatus*; *Atrypa compressa* (7.) I do not now know. So you see every quoted species may be as well, nay better, interpreted as belonging to Bala beds...."

He then shortly notices the very meagre list of fossils derived from the Coniston grits, viz. *Cardiola* and *Orthoceratites*; and he adds, "As *Cardiola* is so plentiful in the Coniston flags, no wonder it should often occur in the grits; and as for the *Orthoceratites*, they prove nothing against the grits being Caradoc. The species, if named rightly, is *O. Ibex*, and this occurs in the Coniston limestone; but the grit specimens are not good.... We now know how barren the Caradoc sandstone often is; and that (in Westmoreland and Cumberland) it should contain some fossils from the beds below, is no wonder." The previous quotations from Mr. Salter's letter are given (as far as possible) word for word; and are perfectly to the point.

To avoid all doubt, I sent the previous list of seven species, with an additional query respecting *Orthoceras Ibex*, to Professor M'Coy, who is now in Ireland, in order that he might inform me how he had determined their geological place in the second Fasciculus of the 'Cambridge Palæozoic Fossils.' The proof-sheets of this work have for several months been under revision; the plates and catalogues were finished during the past summer; and the whole work, but for the, perhaps unavoidable, delays of the University Press, would before this time have been published.

His reply (dated Nov. 12, 1851) contains the following critical remarks:—"1. As to *Cardiola interrupta*, you have it, from the black shales north of Builth (Llandeilo group), in your museum. 2. Of the other Coniston flag fossils, *Creseis* (so called) is common enough in the same black shales (Caradoc shale). 3. *Orthoceratites* prove nothing, the species being undetermined. 4. *Graptolites Ludensis* (not *G. priodon*) occurs from the Scotch graptolite-slate up to the Ludlow. 5. *Astræa ananas* (so named in your list) has no generic or specific relation to that Wenlock species. It is a species of Linné, *Sarcinula organum* (first described as British in 'Camb.

Fasc.' p. 37), and is extremely common in the Coniston limestone localities, and not found higher by you. 6. The *Asaphus caudatus* of your list is not that upper species, but is totally distinct. It has been described and figured (*Odontochile obtusicaudata*, Salt. sp.) in the 'Camb. Fasc.,' p. 161, and is very common in the Bala limestone and flags of Coldwell (Coniston group), and not known in any higher position. 7. The *Atrypa compressa* of your list I found so labelled in your collection. It has, however, no generic or specific relation to that fossil, but is the *Siphonotreta Anglica*, Mar., the only other known specimens of which were found in the Wenlock shale. Therefore this fossil list, as now examined, supports your views; for those (very few) upper Silurian species which were correctly identified from the first are well known to exist also in the undoubted Bala beds and Caradoc shale with *Trinucleus*, *Ampyx*, and other characteristic Cambrian forms." I may just remark that Prof. M'Coy has in the first instance used the words *Caradoc shale* incorrectly; for I have never used these words to describe any black shales (although such do sometimes appear) under the Caradoc sandstone. The black shales north of Builth are undoubtedly a part of the Llandeilo or Bala limestone group. "As to the *Orthoceras Ibex* (he adds), the specimens I have named in your museum prove that it occurs, in my opinion, from the *Upper Ludlow* to the *Coniston limestone* inclusive." These determinations had been made by Prof. M'Coy, without a view to any previous hypothesis; and seem also to be conclusive as to the age of the *Coniston flags*. On this point, he and Mr. Salter are in perfect agreement.

Should I receive any new information during this spring respecting the fossils of the Coniston grits, I shall rejoice to communicate it to the Society. But I have now no doubt respecting the true sequence of the deposits between the central group of Cumberland and the Old Red Sandstone. The successive deposits, when arranged in the following corrected order, agree physically and zoologically with the whole sequence of North Wales—Cambrian and Silurian.

Ascending section from the centre of Skiddaw Forest to the Carboniferous Limestone near Kirkby Lonsdale.

1. *Granite*; in some places sending veins into the overlying metamorphic Skiddaw slate.
2. *Metamorphic slate*; near its base resembling, but never a true, gneiss; quartz-rock; mica-slate; chiastolite in mass; chiastolite-slate gradually passing into a dark glossy clay-slate, &c. &c. It is traversed near the granite by many poor metalliferous veins containing abundantly many well-known Cornish minerals, such as wolfram, schorl, apatite, &c.
3. *Lower Cumbrian group, or Skiddaw slate*; of very great thickness. Prevailing rock a dark glossy clay-slate that does not effervesce with acids. Many coarser beds, irregularly distributed, very rarely as coarse as millstone grit. Fossils very rare—*Fucoids* and *Graptolites*. No shells found in it.

4. *Upper Cumbrian group.* (1.) Great stratified contemporaneous masses of porphyry, trappean conglomerates cemented by felstone-porphyry, trappean shales (*schaalstein*)—all frequently alternating with great beds both of coarse and fine chloritic slate; altogether of enormous thickness.

(2.) *Coniston limestone* and calcareous slate; partly interlaced with the top beds of the preceding. Thickness 200 or 300 feet.

(3.) *Coniston flagstone*; in its upper beds containing here and there some thin calcareous bands. Thickness about 1500 feet.

Of these three sub-groups, (1) represents the lower Cambrian rocks of N. Wales; (2) and (3) represent the Bala limestone and the beds over it; and therefore represent, though on a rather degenerate scale, the upper Cambrian groups of North and South Wales.

5. *Coniston grits.* Thickness variable; on the average, not perhaps less than 1500 feet. The exact equivalent of the Caradoc sandstone—the lowest group of which the true relations are made out in the sections of the 'Silurian System.'

6. *Ireleth slates*; composed, in the ascending order, of—(1.) Dark calcareous slates. (2.) Calcareous slates with concretionary bands of limestone. (3.) Upper Ireleth slates. Collectively of great thickness; and the near equivalents of the Wenlock shale and limestone.

7. *Coarse slate, flags, grits, &c.*; not physically well separated from the preceding group of Ireleth slates; but higher in the section, and therefore approximately the equivalents of the lower Ludlow rocks, and of great thickness.

8. *Rocks of Kirkby Moor.* The highest group of the series. Fine and coarse flagstone, coarse bands of slate, grits, red flagstone, &c. It is the equivalent of the *upper Ludlow rocks and Tilestone*, and abounds in *upper Ludlow fossils.*

9. Old red sandstone.

10. Carboniferous limestone.

This arrangement may be more clearly shown in the accompanying table:—

Palæozoic Rocks of Cumbria.

			ft.*	
Carboniferous Limestone.				
Old Red Sandstone.				
Silurian Series.	Flags and grits of Kirkby Moor		800	= Upper Ludlow.
	Coarse contorted slate and gritstone		800	= Lower Ludlow.
	Ireleth slates.	Upper Ireleth slates	500	= Wenlock group.
		Lower Ireleth slates. Calcareous slates	80	
		Lower Ireleth slates. Dark slates	200	
	Coniston grit		2000	= Caradoc sandstone.
Cambrian Series.	(Upper Cumbrian.)	Coniston flagstone	1500	= Upper Cambrian (Bala, &c.) of N. Wales.
		Coniston limestone	300	
		Slates and porphyry	10,000	= Lower Cambrian of N. Wales.
	(Lower Cumbrian.)	Skiddaw slates	6000	
Metamorphic slates.				
Granite.				

* These are given merely as approximate measurements.

The previous arrangements are not without their importance; for in consequence of the general absence of fossils among the Cumbrian slates and porphyries, one might have started the hypothesis, that these slates and porphyries were but an exaggerated development of the upper Cambrian groups, and that the Skiddaw slate was only an expansion of the dark slates at the bottom of the Bala group. Such, indeed, was an hypothesis suggested to me, in conversation, by M. Barrande; but it is clearly untenable.

The descending sections of Cumberland, commencing with the Coniston limestone, are far more vast than the sections of Wales below the Bala limestone; although we include therein the most deeply seated stratified rocks within the limits of the Principality.

§ 2. *Sections of May Hill, Horderley, and Woolhope, &c.*

During the past summer I had the great advantage of visiting a part of the typical Silurian country under the guidance of my friend the Rev. T. Lewis; and, at the time, I had not the remotest hope of adding, during a very short visit, any scrap of information worth recording after the ample details published by Sir R. I. Murchison and Professor Phillips. My only hope was that I might add a few good fossils, new or old, to the Cambridge Museum. I may, however, be permitted to remark, in passing, that the colour for the Caradoc sandstone ought in some places to be a little more extended than it was upon the original map of the 'Silurian System,' for immediately overlying the Caradoc sandstone of the Horderley section is a shale, with abundant specimens of *Ampyx* and *Trinucleus*, which runs down to the bridge over the Onny a little below Cheney Longville. This, perhaps local, deposit might, I think, be conveniently called Caradoc shale; and my occasional use of this term, during past years, has, I suspect, led Professor M'Coy into the slight verbal mistake to which I before alluded.

Again, it seemed, from the copious details published by Professor Phillips, that there were some other doubtful lines of demarcation even among the most typical Silurian groups. To determine any of these minute and critical questions would have required a detailed examination, for which I had no leisure; but I did collect, with the help of Mr. Lewis, a small but good series of fossils from the highest beds of the May Hill section, which rise immediately from beneath the undoubted Wenlock group. This series, determined by Professor M'Coy, was as follows:—

(1.) *Halysites catenulatus* (Dudley).
(2.) *Encrinurus punctatus* (Dudley).
(3.) *Pentamerus microcamerus*.
(4.) *Leptagonia depressa* (Dudley).
(5.) *Leptæna transversalis* (Dudley).
(6.) *Orthis turgida* (?).
(7.) *Spirigerina reticularis* (Bala to Devonian).
(8.) *Strophomena pecten* (Dudley).
(9.) *Hemithyris navicula* (Ludlow).
(10.) *Euomphalus funatus* (Dudley).

In reply to some questions, arising out of this list, he writes as follows:—"Of the above ten species all but two are common Dudley species. One of these two seems to be very local, and the other is of doubtful identification. All the corals, of which I have unfortunately mislaid the list, are Wenlock species; and several of them have not hitherto been described from any lower beds. Several of the above shells are also found in the Caradoc and Bala rocks; but some of them (as *Euomphalus funatus*—very abundant at May Hill—and *Hemithyris navicula*) are not. Lastly, I have not yet found in your May Hill series, *Leptæna sericea*, or any of those *common* Caradoc or Bala fossils which may be considered as characteristic, because not also found in the Dudley and Wenlock series." Shall we then, in such a case as this, strike off the upper beds of the Caradoc group, and pack them with the overlying group under some new name, such as Wenlock-grits? Provisionally I will accept what appears to be Professor Phillips's interpretation of such phænomena; viz. that the faunas of the two groups are not separated by any well-defined geometrical line, but rather by an ambiguous boundary, near which each fauna occasionally overlaps the other. But the above facts do seem to show that the Caradoc group (the lowest Silurian group ever made out stratigraphically by the author of the 'Silurian System') was the true connecting link between the Silurian and Cambrian series.

Lastly, I may shortly notice another minute question, before I go on to more general considerations. In 1846 I spent a few hours with Dr. Davis in looking at the sections near Presteign; and I expressed an opinion that the Presteign limestone must be the equivalent of that at Woolhope. I did not then remember the place assigned to it by Sir R. I. Murchison. Not long afterwards my friend Mr. Davis read a paper before the Society*, in which he briefly alluded to, and controverted, my verbally expressed opinion. In reply, I at the time stated the grounds on which I had arrived at it; viz. that the Presteign limestone *rested immediately on the Caradoc group*, without the intervention of any distinct argillaceous deposit; and that the same limestone was *overlaid by an argillaceous deposit*, which seemed very well to represent the Wenlock shale. The position of this limestone in the section seemed, therefore, to be exactly that of the Woolhope limestone. Mr. Davis also published a copious list of fossils from the Presteign limestone†; and as they agreed generally with the well-known Wenlock species, that fact was considered as almost conclusive in deciding the previous question.

Never having traversed the beautiful Woolhope sections since 1834, I was anxious to revisit them during the past summer; and in an excursion of a few hours, I examined, in company with Mr. Lewis, several of the quarries in the Woolhope limestone; and obtained from them the following fossils, which have been named by Professor M'Coy:—

Bumastus Barriensis (Wenlock).
Phacops caudatus (Wenlock).

* Quart. Journ. Geol. Soc. vol. vii. p. 432.

† *Loc. cit.* p. 437.

Spirigerina reticularis (Bala to Devonian).
Leptæna depressa (Bala to Carboniferous).
Strophomena euglypha (Wenlock).
Strophomena Pecten (Bala and Wenlock).
Homalonotus Delphinocephalus (Wenlock).
Cornulites serpularius (Wenlock and Ludlow).

Two conclusions seem to follow from such a list; first, that the fossil lists of the Presteign limestone (given by Mr. Davis), do not prove it to be of the Wenlock age; for by the same argument we might identify the Wenlock and Woolhope limestones, although actually separated from one another in the same section; secondly, that the Woolhope limestone might very properly have been called a lower Wenlock limestone, and that it cannot, with propriety, be considered as the highest sub-group of the Caradoc sandstone. These conclusions seem to be in accordance with the published views of Professor Phillips.

§ 3. *Comparison of the three great groups of the Lake Mountains, with the Cambrian and Silurian groups of North and South Wales.*

I will first enumerate (*in ascending order*) the several groups into which the whole Welsh series (Cambrian and Silurian) may, I think, be conveniently subdivided; and I may premise, that I consider all the palæozoic rocks, from the lowest Cambrian to the highest Permian, as one system—the primary or palæozoic system. This primary system admits of three great subdivisions; viz. a lower subdivision, including the Cambrian and Silurian series; a middle, including the Devonian series; and an upper, including the Carboniferous and Permian series. These three subdivisions belong to one great *systema naturæ*, the subordinate parts of which often pass one into another, by almost insensible gradations; although the species in the several subdivisions and subordinate groups often entirely, or almost entirely, change*. But the *primary system*, thus defined, differs entirely from the *systema naturæ* of the *secondary system*; and, in like manner, the *systema naturæ* of the secondary system differs almost entirely from the *systema naturæ* of the tertiary system. Lastly, we have the actual *systema naturæ* of the living world; but between the *tertiary system* and that of living nature no one has yet drawn any intelligible line of demarcation.

I do not pretend to answer a question, whether the primary, secondary, and tertiary systems may not, in progress of discovery, be at length brought in a similar intimate relation; neither do I discuss a question respecting the expediency of any further subdivisions of the secondary system. A good classification only represents the actual condition of our knowledge; and the following remarks relate only to the classification of the subordinate groups of the lower palæozoic system, as above defined. To avoid all verbal ambiguity, or

* This view of regarding all the Palæozoic rocks as of *one system* is not new. It has often been discussed in this Society; and it was formally advanced by myself in 1843.—*Proceed. Geol. Soc.* vol. iv. p. 223.

wrangling about the use or abuse of the word "system," I will provisionally separate the whole *lower palæozoic series* into two great natural subdivisions—Cambrian and Silurian; each of which may be again subdivided into a series of stages or groups, which, collectively, I here designate by the names CAMBRIAN SERIES and SILURIAN SERIES. The Cambrian and Silurian collective groups, thus defined, have a well-marked physical separation; and the Silurian groups are, not unusually, unconformable to the Cambrian: and although several fossils are common to the two collective groups, especially near the planes of junction, yet the fossils of the well-defined lower stages of the Cambrian series are very widely distinct from the fossils of the upper stages of the Silurian series. I believe that this is the case in Wales and Siluria; and I am certain that it is the case in the Cumbrian cluster of mountains. The fossils of the Coniston calcareous slates hardly reappear at all, and certainly not as a group, among the very numerous fossils of the rocks between Kendal and Kirkby Lonsdale (Upper Ludlow). Hence, on mere palæontological grounds, it would produce nothing but confusion were we to designate the Ludlow rocks south of Kendal, and the calcareous slates of Coniston, &c. as one system, while we adopt the restricted use of the word "system" now in common use.

After these preliminary remarks, I proceed to enumerate the several groups into which the whole Cambrian and Silurian series may, I think, be conveniently separated. I profess not to describe the granite and other igneous and unstratified rocks; but I may just notice the metamorphic slates of Anglesea and Caernarvonshire, composed of quartz-rock, quartzose mica-slate, quartzose chloritic slate, crystalline limestone, serpentine, &c. That they are of great antiquity is certain; for they appear to underlie, and they certainly do not overlie, the old rocks in the great S.W. promontory of Caernarvonshire. That they are truly hypozoic, or that they are older than any of the unaltered slate-groups of the Principality, is by no means certain; but these are points quite foreign to the discussions of this paper.

On the eastern side of the Menai Straits is an expansion of some dark slates, which I was at one time induced to consider (hypothetically, however, and without any direct proof) as the lowest unaltered slates in North Wales, and perhaps the equivalents of the Skiddaw slate. In 1846 I changed this view, chiefly on mineral evidence, and arranged the dark Menai slates in the same group with the black slates of Tremadoc. The change, which I made on imperfect evidence, has been since established on better evidence by Professor Ramsay and the gentlemen of the Government Survey.

The whole Cambrian series is exhibited, in vast undulations, from the Menai to the Berwyns; and a part of it, again, in a system of what might be called short independent waves, on the east side of the Berwyns, until the last beds of the series become buried under the carboniferous limestone. But, if we extend our views to the north end of the great undulating series, we find (not, however, without continual breaks and dislocations) the prevailing strike and dip so

changed, that the successive beds are seen to plunge, with a northern dip, under the rocks forming the base of the great deposits of Denbigh flagstone which compose the true Silurian series of North Wales. In this view, the physical separation of the Cambrian and Silurian series is not hypothetical, but perfectly natural; and the zoological separation, taken on the whole, is, perhaps, as complete as the physical. Sections, illustrative of these points, I have exhibited many times before this Society, and I must not now attempt to reproduce them.

The first question which arises, when we attempt to separate the great Cambrian series into subordinate groups, is this:—What is the base of the whole series? Properly speaking, there is no true mineralogical base in North Wales, unless we take the metamorphic rocks as a kind of hypothetical base; but the lowest groups of the whole series may, if I mistake not, be seen on a part of what I have called "the great Merioneth anticlinal," and also among the red-coloured slates which rise from below the great quarries of Nant Francon and Llanberris.

If this conclusion be true, there are two base-lines, on either of which we might construct an ascending section through the Cambrian rocks; and, knowing the importance of putting this view to the test, I employed my friend John Ruthven, in 1846, to seek for fossils in the dark slates of the Menai, and also among the beds which form the great ascending section east of the Bangor slate-quarries. But he failed in finding any fossils in the dark slates, and we both failed in finding the Lingula-beds where I expected them; although it was obvious, from analogy, that they ought to be found a *little above* the coarse grits (Harlech grits) which overlie the Bangor slates.

During the following year I wrote to my friend Mr. Jukes, informing him of my assumed base-line, and of the position I had, from the first, given to the Harlech grits, where they were represented in the Caernarvon chain; but I added that my scheme was defective in fossil evidence, since I had failed in discovering the Lingula-flags above the beds, which seemed very well to represent the Harlech grits. In his reply he informed me that Professor Ramsay and his fellow-labourers had found, and found in their right place, the beds for which I had more than once sought in vain. I have stated these facts, in a few sentences, to show that I have no wish to appropriate to myself discoveries which are due to others, and that I have never put forward any views respecting the grouping of the Cambrian series in a rash and hypothetical spirit. I now consider it beyond all doubt that there are, as stated above, two base-lines (on the same geological horizon), on which we might proceed to construct the successive groups of an ascending natural section through the Cambrian and Silurian series.

The *Bangor group* (No. 1).—In the accompanying tabular view under the term "Llanberris slates" are included not merely the slates of the great quarries of Llanberris and Nant Francon, but a series of slates and hard grits, with a few bands of porphyry, which undulate towards the west, and are partly cut off by a great mass of

felstone-porphyry, and partly buried under drift. The Harlech grits make a well-defined, and sometimes a very striking feature in the chains of Caernarvonshire and Merionethshire. They may be traced almost continuously from Aber, and thence on the eastern side of the line of slate-quarries into the great precipices of Craig Goch; forming great gnarled masses of rock as coarse as millstone-grit, often beautifully jointed, sometimes with traces of cleavage-planes, and often alternating with very thin bands of chloritic slate. Again, they are well seen near Trowsfynydd, and afterwards on both sides of the great Merioneth anticlinal; and they form the most striking features of the Rhinog Fawr chain, dipping towards the N.W. But this dip is reversed by a synclinal curve, and the same great beds of grit are brought to the coast at Barmouth and Harlech, bearing within their trough some of the lower beds of the Festiniog group. On this latter point I ought not, however, to write with confidence, as I have never

Tabular View of the Palæozoic System.

PRIMARY OR PALÆOZOIC SYSTEM.

					ft.*
Upper	Permian series.				
	Carboniferous series.				
Middle	Devonian series	Petherwin group...	Petherwin slate and Clymenia limestone.		
			Marwood sandstone.		
		Caithness group ...	Hereford sandstone, marl, and cornstone.		
			Dipterus flags.		
		Plymouth group ...	Dartmouth slate.		
			Plymouth limestone and red grit, and Liskeard slate.		
Lower	Silurian series ...	6. Ludlow group...	*c.* Upper Ludlow		400
			b. Aymestry limestone ...		100
			a. Lower Ludlow		500
		5. Wenlock group..	*c.* Wenlock limestone ...		100
			b. Wenlock shale		800
			a. Lower Wenlock, or Woolhope limestone		100
	Cambrian series	Upper	4. Caradoc group.....	*a.* Caradoc sandstone, limestone, and shale..	1500
			3. Bala group..	*b.* Upper Bala (including Bala and Hirnant limestones, shale, flagstone, and conglomerate) ...	4000
				a. Lower Bala; dark slates, flags, and grits	4000
		Lower	2. Festiniog group.....	*c.* Arenig slates and porphyry	7000
				b. Tremadoc slates	1000
				a. Lingula flags.....	500
			1. Bangor group.....	*b.* Harlech grits.....	500
				a. Llanberris slates	1000
Metamorphic.					
Granite.					

* These measurements, like those in the preceding table of the Cumbrian Rocks, p. 141, are merely approximative.

crossed the Rhinog Fawr chain since 1832. Lastly, the Harlech grits form the extreme point of the promontory south of Tremadoc; and they may be traced round the great southern headland of Caernarvonshire from St. Tudwal's Island to Hell's Mouth. I have thought this short explanation necessary, in order to show what is here meant by the lowest Cambrian group of the Tabular View.

The *Festiniog group* (No. 2), taken collectively, and where it is well developed, is not, I think, less than 9000 or 10,000 feet in thickness. Its lowest sub-group (Lingula-flags) is best seen to the south of Festiniog and Tremadoc; but for details respecting it, I must refer to my former papers. The mineral structure of the Tremadoc slates is very peculiar. It is sometimes penetrated by metalliferous veins, and it contains beds or large concretionary masses of magnetic and pisolitic iron ore. This iron-ore is a good finder for the group, as I can assert on personal experience. It exists, for example, in the country east of St. Tudwal's Road, in the black slates between Clynog and the Rivals, at Tremadoc, on the east side of the Merioneth anticlinal, and on the N.W. flank of Cader Idris; and in all these places it defines the position of the sub-group, whatever other mineral modifications it may have undergone.

The third sub-group, Arenig-slates and porphyries, is of vast thickness, and in general structure is almost the exact counterpart of the green-slates and porphyries of Cumberland. The whole mass is stratified very regularly, and in its upper portion are irregular concretionary beds of dolomitic altered limestone, without fossils. The trappean beds, whether erupted or recomposed (such as trappean conglomerates, trap-shale, &c.), are of very variable thickness; and where they are degenerate, the regular slates expand, and sometimes contain fossils. Arenig and Cader Idris may, perhaps, be near the centres of plutonic eruption; but they are regularly stratified, and I never found among them any which I thought true subaërial products.

The *Bala group* (No. 3) is also of great thickness. It may be divided into two sub-groups, the lowest member of which is finely developed in a mountain-ridge of dark pyritous and rather earthy slates (in some places, however, forming a good roofing-slate), which overlies the S.E. flank of Cader Idris: the same dark slates appear on the east side of Arenig. But I must not here describe the great succession of earthy and arenaceous deposits, slates, flag-stones, &c., often highly fossiliferous, and more or less calcareous, which form the lower Bala group, and conduct us to the Bala-limestone. For details I must refer to my published papers and abstracts.

The Upper Bala group (No. 3, *b*), in North Wales, cannot, I think, be less than 4000 feet in thickness; it begins with the Bala-limestone, to the east of Bala, and includes the Hirnant limestone and shelly sandstone; and it includes, near its upper surface, some arenaceous flagstones; and (if I have not misinterpreted some obscure sections) ends with dark indurated shales, here and there passing into a bad pyritous roofing-slate.

Over the group last-noticed is a series of beds of considerable

thickness, made up of arenaceous flags and grits, sometimes of coarse structure. It occupies a trough, on the east side of which the Bala-limestone is repeated over again. This arenaceous deposit was the highest member of my original Cambrian series; and I need not inform the Society that it is now identified, in the Government Survey, with the *Caradoc sandstone*.

Beyond this eastern line of the Bala-limestone, there is an outcrop of older Cambrian rocks*; after which the whole sequence is broken by enormous faults. The strike of the beds is suddenly shifted; irregular and newer fossiliferous beds appear on the east side of the Berwyns in a state of extreme contortion, and with a new strike. But through the range of these contorted beds runs an irregular axis of an older Cambrian group, which throws the shelly masses on one side towards the north, and on the other towards the south. On the north side they are finally carried under the Denbigh flagstone; to the south, after many undulations, they pass under the flagstone series of Meifod and Welsh Pool.

That the flagstones of Welsh Pool and Denbighshire were nearly on one parallel, I never had a doubt since 1832. They both belonged to one series, afterwards called "Upper Silurian." But what were the limestones and shelly sandstones of Meifod and Llansainffraid? I could connect the Llansainffraid beds with the beds at the north end of the Berwyns by an unbroken line of strike; and therefore the Llansainffraid beds (and consequently the Meifod beds) were a part of the Cambrian series; and the fossils seemed to sanction this conclusion, for the Meifod fossils and Bala fossils seemed to be almost identical in species.

Such is the *great Cambrian series*, as determined by myself, after nearly nine months of hard labour, during the summers of 1831 and 1832; and such was, on all essential points, the account I gave of it before the British Association in 1833,—a great series of deposits, commencing to the east of the Menai, and rolling through the mountains in rapid undulations, till the base-line is repeated in the Merioneth anticlinal. From this base-line to the top of a portion of the Berwyns, the whole series is exhibited in an ascending section, which displays, in order, the four successive groups of the tabular view, collectively not less than 20,000 feet in thickness.

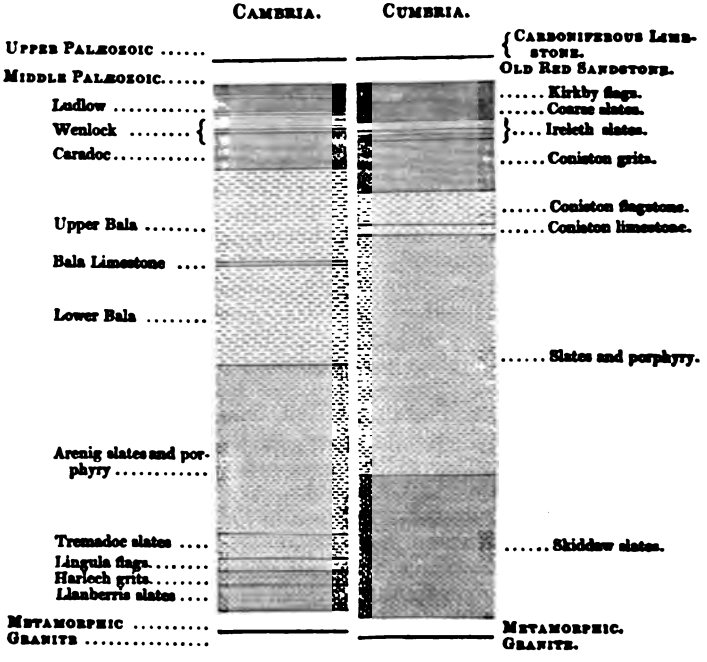
We now know, through the noble map published under the direction of Sir H. De la Beche, that the *highest group* of the great ascending section is the equivalent of the Caradoc sandstone of the "Silurian System." Hence this group, as interpreted by the Government Surveyors, would be common to the Cambrian and Silurian rocks, described by Sir R. I. Murchison and myself,—the highest Cambrian group of my section being coincident with what they regard as the true Caradoc sandstone; and it is this supposed overlap which introduces the only real ambiguity in the development and nomenclature of the lower palæozoic rocks of North Wales †.

* Proceed. Geol. Soc. vol. iv. p. 253.

† To make this more clear, I may state, that the Caradoc sandstone of the well-known Horderley section contains numerous fossils of the Bala group, and none of

After these remarks, we are at once prepared to compare the rocks developed in the great transverse sections of the Welsh and Cumbrian mountains. The lower Cambrian groups (Bangor and Festiniog, Nos. 1 and 2 tabular view) are amply represented by the green slates and porphyries of Cumberland. The upper Cambrian groups (Bala and Caradoc, Nos. 3 and 4) are (however imperfectly in thickness) clearly

Diagram illustrating the Comparative Development of the Silurian and Cambrian Rocks in Wales and Cumbria, respectively.



represented by the Coniston limestone, flagstone, and the hard coarse grits of the Westmoreland sections.

The equivalents, in the North of England, of the Wenlock and Ludlow groups (Nos. 5 and 6) have already been noticed. Using the words "Silurian System" in any definite sense, these are the groups which truly and exclusively belong to it as a system; for the Caradoc

the characteristic Wenlock species; while the so-called Caradoc sandstone of May Hill contains the Wenlock fossils in abundance, and none of the characteristic Cambrian types. But is there a single section in which these two distinct groups of fossils appear together in one stage? If no such section can be found, why may we not suppose that the Caradoc sandstone of Horderley? Should we ever be able to answer this question in the affirmative, the ambiguity alluded to in the text would be at an end. The statement here given is drawn from the fossil evidence supplied by the Cambridge Museum.

group (No. 4) belongs, palæontologically, more to the Cambrian than to the Silurian series.

Before I left the Principality in 1832, I made some hasty traverses through the lower palæozoic rocks of South Wales, between the "Silurian System" and the coast of Cardiganshire. In each traverse I met with the same kind of perplexing undulations,—slate-rocks, flagstones, grits, sandstones, and conglomerates repeated again and again. As a general rule, the conglomerates seemed most largely developed near the western limits of the several sections, where the higher mountain-ridges ended, and lower ridges of rocks, afterwards called Silurian, began; and, as another *general rule*, the rocks forming the immediate outskirts of the mountain-ridges dipped towards the interior, so as not (at least in appearance) to pass under these Silurian rocks.

What then was the age of this undulating system of Cardiganshire, &c.? It was superior to the great group of Cader Idris (No. 2, *c.* of the tabular view). Many portions of it were superior to the Bala limestone. This was proved to demonstration by the sections at the south end of the Berwyn chain near Mallwyd. Hence the whole system represented No. 3 and No. 4 of the present tabular view; and, agreeably to a nomenclature I afterwards adopted, was a great expanded development of the *Upper Cambrian* series*.

I had two objects in making these rapid traverses through the older rocks of South Wales; viz. to make out so much of the general structure of the country, as to learn how I might best attack it during the following summer; and especially to find the prolongation of the Bala limestone or its equivalents. Another summer came, during all the early months of which I was crippled and unable to wield a hammer; and, as for the Bala limestone, I neither found it, nor could I ever make out with any certainty what was its exact representative among the undulating masses of South Wales. As to the groups afterwards called the Llandeilo flags, and the other beds afterwards coloured Silurian in the 'Silurian System,' it formed no part of my task, nor had I any time to study their relations. I knew that the author of the 'Silurian System' had placed them *over* the great undulating slate-rocks of South Wales; and in two places, where I gave them in 1832 a passing look, I saw them apparently dipping under undoubted newer groups, now known as Upper Silurian.

My object in this retrospect is to show, that before I studied a single section under the guidance of the author of the 'Silurian System,' and long before I had exchanged a word of amicable controversy with him, my conception of the relations of the great Cam-

* In formerly using the terms "Upper Cambrian System" and "Lower Cambrian System," I neither asserted nor believed that the two series were capable of being separated by distinct groups of fossils. All the evidence I had before me rather tended to an opposite conclusion. The terms seemed, however, convenient, as giving us a good physical subdivision of a great complicated series of deposits, and, at the time I first adopted them, were perfectly in agreement with the language current among geologists,—simply designating a series of groups considered, as a matter of convenient arrangement, apart from the rest of the groups in a general section.

brian series was exactly what it is now. At the end of the summer of 1832 I had *made no mistake in principle* in my interpretation of the phænomena of North and South Wales, so far as I had studied them; and most of my best sectional illustrations of the structure of Wales, published afterwards in successive papers, have been copied, line for line, from sections made in the field during the summers of 1831 and 1832.

§ 4. *Historical retrospect of attempts to unite the Cambrian and Silurian rocks in a continuous section.*

In 1834 I studied for the first time the Silurian types under the guidance of my fellow-labourer and friend, the author of the 'Silurian System'; and I was so struck by the clearness of the natural sections and the perfection of his workmanship, that I received, I might say, with implicit faith every thing which he then taught me. We did not, however, discuss or examine together the base-line of his system; nor did I then, or ever afterwards, comprehend the evidence on which he attempted to define its limits. The whole "Silurian System" was, by its author, placed, as before stated, *above* the great undulating slate-rocks of South Wales; although the only sections I had personally examined in 1832 rather seemed to indicate a contrary position. I knew the labour he had bestowed on his Map, and that he had traced his base-line through a distance (following its sinuosities) of at least 200 miles. Hence, although I saw no good reason, either physical or palæontological, for fixing the base-line of his system exactly where he placed it, I did not at that time entertain a thought that he might perhaps have mistaken the geological relations of his lowest groups.

After making a partition of the country, in which all the formations to the north of Meifod fell to my lot, my fellow-labourer, at my request, made a traverse with me through the undulating calcareous and fossiliferous rocks between Meifod and Llanrhaidr; and he identified, without any reserve, the Meifod series with his most typical form of Caradoc sandstone; and an outlying mass of calcareous slate above Llanrhaidr, he pronounced to be Llandeilo flag. I reluctantly accepted these two determinations; for they involved the upper divisions of my Cambrian sections in most perplexing difficulties, respecting which I had no misgivings, when in 1833 I explained my sections of the Welsh series to the British Association.

We then traversed the Berwyn chain to Bala; and from the top of the pass I explained to him the position of the whole Bala group, extending to the foot of the Great Arenig, the position of the Bala limestone in the group, and the beds *over* the Bala limestone, which at the south end of the chain were sent off in great undulations, and formed a considerable part of the Upper Cambrian groups of South Wales.

We then collected fossils from the limestone-quarries near Bala; and a glance of the eye was enough to show, that, as a group, they nearly agreed with the (so-called) Caradoc fossils of Meifod. Yet such was the conviction produced by the sections from the top of the

Berwyns to Bala, that my friend left me (and it was the last time we ever met to work together in North Wales) with a most express declaration that *the Bala groups could not be brought within the limits of his system*. At that time therefore (1834) he knew that the lower beds of the Silurian series, and the upper beds of the Cambrian series, could not be at once separated by their fossils. And this opinion has been expressed by me, again and again, in my published papers, as well as in the reiterated discussions before this Society.

Such was my confidence in the decisions of my friend on any question respecting Silurian rocks, that I accepted his determination of the Meifod group, I might say, with implicit faith, and set it down as Caradoc. But, in that case, the beds of Glyn Ceiriog, and many other beds on their strike, and skirting the northern limits of my Cambrian series, must also be Caradoc. I supposed, therefore, that several masses of calcareous slate (such as those of Cader Dinmael, Penmachno, &c.) *might* have been put in a false position in my field-sections; and that in truth they *might be subordinate* to the conglomerates, grits, and flagstones, &c., which range not far from the Holyhead Road, at the base of the Denbigh flags; in which case they must come into a true Caradoc group. Such was the hypothetical conclusion to which I was driven.

I had then no opportunity of putting this hypothesis to the test; but the next time I visited North Wales (1842), in company with Mr. Salter, I found at once that the calcareous slates above-mentioned were not subordinate to the group I had called Caradoc sandstone. On the contrary, they were all undoubtedly subordinate to the great Bala group, and therefore a part of my Cambrian series. It followed, therefore, that I had hypothetically tortured the upper groups of my Cambrian series to make them fit to the lower groups of the Silurian series. In this I had done wrong; for the event has proved that my Cambrian sections were right in principle, while the lower groups of the Silurian sections were wrong. From this time (1842), I began to lose my confidence in the stability of the base-line of the "Silurian System."

From 1834 to 1842 I had accepted Sir R. I. Murchison's conclusion, and made the Meifod beds Caradoc or Silurian, and the Bala beds Cambrian; but the only hypothesis on which this conclusion could be maintained was dissipated at the first so-called Caradoc quarry which I examined in 1842 in company with Mr. Salter. I need not allude to our joint labours in 1842 and 1843. I did not during those two summers alter a single important line in my Cambrian sections; but what did the subdivisions of the sections mean? That was to be settled by the fossils, and I had a friend with me who could give me, I thought, an oracular response. He concluded on fossil evidence, and the conclusion was borne out by the sections, that the Meifod and Glyn Ceiriog and Bala beds were nearly on one parallel. Hence, if the Meifod beds were Caradoc, the Bala beds must also be Caradoc, or very nearly on its parallel. But if so, it followed almost of necessity, that the great undulating masses of sandstone between Mallwyd and Can Office must be Upper Silurian. And, by

like reasoning, it also followed, that the grits, conglomerates, coarse slates, &c., which ranged under the Denbigh flags on the north side of the Holyhead Road, and then ran down almost to Conway, must be Upper Silurian. The fossils of these rocks were examined, and they were determined to be Upper Silurian. With one exception (the quarry of Plas Madoc), they were few in number and ill-preserved; and, as they belonged to a group like that of May Hill (above alluded to), no wonder that they were called Upper Silurian.

In my own unassisted examination of these rocks in 1831 and 1832, I called the beds over the calcareous slates of Mallwyd, which extended in undulations to Can Office, Upper Cambrian; and my Upper Cambrian, as before stated, did include the Caradoc sandstone. The grits, conglomerates, &c. under the Denbigh flags, I set down as Caradoc, partly on what I was able to make of the fossil evidence; but mainly on the fact, that the beds in question seemed to overlie my Cambrian series unconformably. My previous determination (in 1832) was right, and our new determination in 1843 was wrong. But far be it from me to blame my friend Mr. Salter for it. He rightly translated the rocks we saw into the Silurian tongue; but that tongue misled us both. In point of fact, we were attempting an impossibility,—we were endeavouring to join my Upper Cambrian series, which was rightly interpreted, to the lower beds of the Silurian series which had been wrongly interpreted and shifted out of their true place in the great continuous Cambrian sections.

All my papers, of which there is any notice in our Proceedings, or Journal, between 1843 and 1846, necessarily partake of the mistakes to which I have just pointed. If the Bala limestone was a Caradoc limestone, the Upper Cambrian system must vanish from my map. I therefore adopted a new nomenclature in my paper in the first number of our Journal *. The whole series, Cambrian and lower Silurian, I called Protozoic. The *Upper Protozoic* groups were on this scheme the equivalents of the *Lower Silurian rocks*. The *Lower Protozoic* groups were what I had before called *Lower Cambrian*; and these groups were the only Cambrian series that remained in this new scheme of nomenclature. But when I speak of my paper in the first number of our Journal (and vol. iv. of the Proceedings), I speak inaccurately. The paper is not mine, and I disclaim its authorship. It is a condensed abstract, made by Mr. Warburton (when President) of two papers read by myself to this Society. This abstract was printed while I was in residence at Norwich. I applied, again and again, for a sight of the proof-sheets as they were passing through the press; but I applied in vain. The President refused my application, and for what reason I never could divine. The abstract is, however, very carefully made; but from a want of a short running comment, which I could have given in a few lines, it is hardly possible to make out the comparative meaning of the sections; and there are a few mistakes introduced into them, perhaps not worth noticing in this place. But the map, with its explanation of the colours, plainly shows that Mr. Warburton did not comprehend the very drift and object of my

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* See also Proc. Geol. Soc. vol. iv. p. 251–269.

papers. I used the word *Protozoic* to prevent any wrangling about the words *Cambrian* and *Silurian*. I gave one colour to the whole Protozoic series, only because I did not know how to draw a clear continuous line upon the map between the upper Protozoic (or lower Silurian) rocks and the lower Protozoic (or lower Cambrian) rocks. This was stated to the Society when my papers were read; nor did I ever dream of an incorporation of all the lower Cambrian rocks in the system of Siluria. Yet as I discovered (to my no small astonishment), for the first time during the past week, he has, in an explanation of the Protozoic, and colourless, portion of the map, written "Lower Silurian (Protozoic)," thereby stultifying my whole paper, the very gist and object of which was to show that there was a great series of groups—lower Protozoic (or lower Cambrian)—below the lowest rocks of the "Silurian System *."

After the erroneous identification of the Upper Bala and Caradoc groups in 1843 (to which I was driven by the identification, above mentioned, of the Meifod and Caradoc groups), I believed that many of the South Welsh undulating slate-rocks would prove to be upper Silurian. I put the hypothesis to the test in several traverses through South Wales, made along with my friend John Ruthven in 1846. In this country, which I had never visited since 1834, we found fossils on every line of traverse, and all of them were of the, so called, lower Silurian types. It was plain, therefore, that the Bala limestone was not Caradoc; and thence it also followed, that the Meifod beds did not belong to the Caradoc group, but to that of Bala. It then became obvious, to demonstration, that in the extension of the Silurian system towards the south-west, beyond the limits of the typical Silurian country, the author of the "System" had made a double mistake,—first, in identifying certain shelly beds of his Llandeilo group with the Caradoc sandstone; and secondly, in placing the same group stratigraphically above the undulating beds I had (I think, very properly) called Upper Cambrian.

This comment would have been uncalled for, had he not made his own mistake a part of the ground for sweeping out all the Cambrian groups from North Wales. I repeat, emphatically, that before 1834

* The map (Proc. Geol. Soc. vol. iv. p. 268) is a mere sketch, which pretty well represents my conceptions of the structure of North Wales in 1843. But it contains some grave errors, which I could have corrected at the first glance: *e. g.* a range of Bala limestone northwards from Llanwddin is properly laid down; but a second band of the same limestone farther to the east (which unites with the former to the south of Llanwddin, in a district where all the beds are inverted) is unfortunately omitted, although it was plainly traced and coloured on my field-map. I suspect that, in the explanation of the blank portion of the rough map exhibited in illustration of my paper, I had written *Lower Silurian and Protozoic*, and that Mr. Warburton, erroneously conceiving the two terms identical, changed the words into *Lower Silurian* (*Protozoic*). Had the published map been allowed to pass, *in its present form*, after a revision by myself, I should virtually have surrendered the whole question now in debate. I do not by any means accuse Mr. Warburton of any *intentional* injustice—quite the contrary: for I know that he gave his best efforts to the abstract. But he had undertaken a task for which he was not prepared, inasmuch as he had never well studied any series of rocks like those described in my papers.

I made no mistake in my general interpretation of the Cambrian series, upper as well as lower. To join the Cambrian series to the Silurian was physically impossible, because a great error had been committed at the point where the upper end of the one and the lower end of the other ought to tally. By whom had this error been committed? Not by myself. But I did all honour to the author of the 'Silurian System.' For twelve years, during which I never revisited his typical country, I believed his base-line to be unassailable; not because I had examined it critically, but because it was he who had laid it down. Twice (in 1834 and in 1843) I changed the nomenclature of some of my upper groups, to bring them into a *supposed* accordance with his Silurian types, and each time I was driven from my hypothesis by a downright *reductio ad absurdum*; and I afterwards returned to my first nomenclature, because I found my sections consistent and true in principle, however imperfect some of them might have been in finish, and in the exhibition of minute details.

This historical statement was absolutely necessary to my present purpose; for all I have published on the questions discussed in this paper has appeared, I might almost say, in a fragmentary form in our Proceedings and Journal. Without this statement it might seem that there had been no steadiness or consistency in my views. But I have been so far consistent, that I never shifted a single group below the Bala limestone. And as to my *upper groups*, though I twice shifted their place, hypothetically, in the hope of bringing them into more near coincidence with the Lower Silurian groups, yet each hypothetical adjustment was abandoned after trial; and I returned to my first grouping and nomenclature because my original sections were right, and because the Silurian sections, at their base, were not merely imperfect, but positively erroneous.

§ 5. *General conclusion.*

It is plain that the author of the 'Silurian System' had gradually lost his confidence in his own base-line; for, in a short sentence of his great work (p. 308), he tells us of the possibility of being induced, at some future time, to move his Silurian base to some greater depth *; yet in the next page he tells us that Moel-ben-tyrch is undoubted Cambrian, although it is superior to the Bala limestone. But questions might have been asked, which, if I mistake not, ought then to have been answered in the affirmative. Would not a change of the base-line necessarily imply some change of nomenclature?—

* In 1834, my friend, on the evidence of the sections, unequivocally excluded the Bala limestone from his lower Silurian rocks, although this limestone was filled with well-preserved lower Silurian fossils. Assuming the truth of the Silurian sections, this evidence was perfect demonstration; for the Llandeilo flags were in the Silurian sections placed *above* all the undulating slate-rocks of South Wales, while the Bala limestone was obviously *below* a considerable portion of them. That all the older rocks of the Cambrian series were to be called Silurian, provided they contained certain Silurian species, was, therefore, an *after-thought* with which I had no means of becoming acquainted; and I believe that this *after-thought* could never have been seriously entertained, had he not discovered that he had mistaken the sectional place of his Llandeilo group.

and, would it not have been wiser and better to retire one step, and to expunge the Llandeilo group from the Silurian rocks, and to base the system on the Caradoc sandstone of the unambiguous sections? Had that step been taken, the Silurian groups would at once have taken their right and undisputed place; and there would have been nothing to stand in the way of the true arrangement of the whole Cambrian series, so far as it is known *. Such a change would only have sacrificed one single group, the relations of which, as we now know, had most certainly been misunderstood by the author of the 'Silurian System'; but instead of this, he shifted his own base-line to the base of the whole Cambrian series†. Thus the name I had given to the Cambrian series, in the elaboration of which I had made no mistake, was to be sponged out; and the series was to receive a new name that was utterly inappropriate.

Our whole scheme of nomenclature of the lower Palæozoic rocks is geographical. This scheme was followed out, from first to last, in the "Silurian System." The system, and all the subordinate groups, were defined by geographical names. Now it is surely an axiom in geological nomenclature, that if we give a new geographical name to any group of strata, that name must refer us to a spot near which we find the group well-developed. In Cambria the whole series of the oldest palæozoic division is more nobly developed than in any other part of Britain (on this point I can speak from my own experience); while in Siluria we find only the highest group of the whole series. This would have been a sufficient reason for changing the name Silurian into Cambrian, had, by any caprice or accident, the name Silurian been first given to the older Cambrian rocks; but it seems to me a very strange reason for changing the name Cambrian (a right name for a great series of rocks well-developed in Cambria, and a name which had the undoubted priority) into Silurian. If indeed we had a good and perfect series of the older palæozoic groups in Siluria, then the words "Silurian System" might be stereotyped as a general designation of all the lower palæozoic rocks of Britain. But Siluria shows us no such typical series, while Cambria does. On the ground, therefore, of geographical propriety, as well as of priority, I vindicate the claims of the Cambrian series for a place in our nomenclature.

* The section from the Menai, over the Berwyns, and to the coast of Shropshire, as explained to the British Association in 1833, differed in no essential respect from the ideal section of the Cambrian series given above in the Tabular View. At the same time I identified (provisionally) the coarse grits near the line of the Holyhead road (Cernioge, Modwl Eithen, &c.) with my friend's shelly sandstone (Caradoc): and as for the Denbigh flagstone, there never was, from the first, any doubt of its identity with the Silurian flags of Welsh Pool and the Long Mountain. My section, therefore, through the whole series (Cambrian and Silurian), was in 1832, excepting in small details, nearly as good as it is now; but the identification (in 1834) of the Meifod beds, by my friend, with his typical Caradoc sandstone, threw the general section into confusion, and destroyed the true key-stone that held the Cambrian and Silurian portions together.

† It has been said (but never by Sir R. I. Murchison) that I was a consenting party to this change. The statement is contrary to fact. The change took place (I believe in 1843) two or three years before I was acquainted with it. Had it been known to me at the time, I should probably have entered a public protest against it.

But my friend and fellow-labourer, and in this instance my antagonist, has told the Society, more than once, that in his final scheme of nomenclature he has only been following out the principles of the Father of English Geology—William Smith. Now this I unequivocally deny. Smith never gave the name to a group first, and made out its place in his sections afterwards. In every instance in which he gave us geological names, his actual sections had the priority of his names by many years: and he never gave a name to any group until he had determined its relations to the groups above it and below it. From his several ascertained groups he collected fossils which he affirmed to be characteristic, and, therefore, a means of identifying distant contemporaneous groups. He used palæontology as a principle of identification only where a typical group had been already well established: but palæontology was not the foundation of his nomenclature; for his names were local or provincial. He never gave a premature name to a local group; and then, on finding that his fossils were not confined to it, proceeded to develope this local group, upwards as well as downwards, through many thousand feet of strata, without changing its original and local name.

In establishing the upper groups of his "Silurian System," the author nobly followed out the principles and practice of Smith. His Silurian sections and fossil lists were side by side; the groups and their relations were well made out; and his names were local or provincial. Thus we all admit the groups in Siluria, so far as they were made out on the principles of Smith; and from Upper Ludlow down to Caradoc they have become typical and classical. But below the Caradoc group the whole base-line of the "Silurian System," from one end of the map to the other, is laid down upon an erroneous interpretation of the real position and relations of both the "Lower Silurian" groups,—first by a mistaken identification of the Caradoc sandstone with a portion of the Llandeilo group; and secondly, by a fatal mistake as to the position of his Llandeilo group, which the author placed *above* the whole undulating series of South Wales*.

* It has been insinuated (not however by Sir R. I. Murchison) that I was the author of this mistake: but I deny the charge should any one repeat it. When I visited the Silurian country in 1834, I did not go to criticise the "System," but to learn the Silurian alphabet from its author. As a matter of fact, we critically examined the base-line together only at one single point, on the north side of Noedd Grugg, where we probably misinterpreted the phænomena; for on revisiting the Noedd Grugg section in 1846, I drew a conclusion from it very different from that at which we had arrived in 1834. My friend has told us that the boundary-line marked on his Silurian map "was simply a geographical and not a true geological line" between the Cambrian and Silurian rocks. That it was not a true geological line is most certain; but was it without meaning? Has he not repeatedly stated the evidence on which the base-line was determined by himself? Assuredly it conveyed the author's views that the rocks on one side of the line were older than the rocks on the other,—that the country coloured Cambrian was older than the country coloured Silurian. Yet through a great part of South Wales the colours are absolutely erroneous, not simply in their geographical distribution, but in their geological conception. Precisely the same error is exhibited in the ideal fundamental section upon which the whole scheme of the Silurian nomenclature is erected (see Map of the Silurian System). There is not either in North or South Wales a single actual section corresponding with the fundamental and ideal section

When this mistake (for years the only stumbling-block in the way of a good arrangement of the lower palæozoic groups) was removed, the author made no new adjustment of his Silurian nomenclature, but proceeded to develope his Llandeilo group—upwards through more than 3000 feet, and downwards through more than 20,000 feet—until at length his Silurian System was spread over all Cambria. Where do we find any proceeding like this among the generalizations of Dr. Smith? My friend and antagonist utterly deserted the principles of Smith, by virtually discarding the force of sectional evidence, and by endeavouring to establish his nomenclature on the mere evidence of fossils; and by then proceeding (through what was called a *downward development* of the Llandeilo flagstone) to involve all the lower rocks of Wales under his lowest Silurian group; although that group was avowedly misplaced and misinterpreted within the comparatively narrow limits of his published sections. Anything in more direct antagonism to Smith's sober inductive habits and scheme of nomenclature could hardly be expressed in language: and this was done while the author was aware that another name (and, I affirm, the right name on the principles of Smith) had been given to that vast and most difficult series of Cambrian rocks which he had not personally examined, yet which he was thus identifying—by a downward and unnatural process of development—with his lowest Silurian group. Nor was this done at all after any assumed right of a second conquest; for, on his part, it was a development of the closet and not of the field.

The author of the 'Silurian System' has informed the Society, in a former controversial paper*, that he himself suggested a name (Snowdonian) for the great series of Cambrian rocks; and from thence he seems to argue that he has a right to change the name. But he did not then know, what was well-known to myself, that the term Snowdonian was quite inapplicable, and that the position of the crest of Snowdon in the general section was doubtful; inasmuch as it merely formed one trough among the undulations of North Wales, between the two, above-mentioned, base-lines of the lower Cambrian series. I readily adopted the good geographical term *Cambrian* to designate the most noble and difficult sequence of rocks within the limits of England and Wales†; but at the same time I strenuously objected to the word *system* (both on geological and palæontological grounds), whether applied to the collective Silurian or Cambrian rocks. This Society heard these objections urged by myself (and I may add by others—especially by Professor Phillips) again and again. I objected to the word *system*, as too definite for our state of knowledge, and I always affirmed that the *Silurian System* was without any good palæontological base.

Since the year 1835 I have repeatedly used the words *upper*

in which the Llandeilo and Caradoc groups are placed in an entirely false position (Quart. Journ. Geol. Soc. Jan. 6, 1847, vol. iii. p. 167). Surely (and quite independently of any question of priority) a nomenclature constructed upon such an erroneous base cannot be considered final, but requires revision and correction.

* Quart. Journ. Geol. Soc. 1847, vol. iii. p. 167.

† I the more readily adopted the word *Cambrian* because it was a very slight change from the word *Cumbrian*, by which I had long been in the habit of designating the corresponding part of the palæozoic series in the north of England.

Cambrian System and *lower Cambrian System*, in conformity with a language in common use—to designate two great collective groups of Cambrian rocks; but I always used these terms in a geographical and geological, and never in any strictly palæontological sense: and that these two collective groups were inferior to all the Silurian rocks I assumed on what I thought an irrefragable authority—that of the author of the 'Silurian System.' That the author's views respecting the meaning of his word "System" were *at first* nearly the same with my own, I am morally certain; otherwise he could not, on the evidence of sections which we examined together, have excluded the Bala limestone from his lower Silurian groups. Had he identified the Bala limestone with his Llandeilo flag, he must inevitably have admitted that his base-line in South Wales was entirely erroneous; but in 1834 (and afterwards in 1839) he was prepared to make no such admission. The strange, and, I may venture to say, the unnatural, hypothesis, that a single group—the Llandeilo flag—might be developed downward through all lower Cambrian groups, and that every rock with the (so-called) lower Silurian fossils (no matter what its place in the great Cambrian series) might "be included in the Lower Silurian group*," was therefore, as I have stated before, an *after-thought*; which never could, I believe, have arisen in his mind, had he not discovered that his own base-line was not merely ill-defined, but founded on a positive misinterpretation.

When, in 1842 and 1843, I had the pleasure of traversing the fossiliferous parts of North Wales with Mr. Salter, I had no expectation whatsoever of finding many fossils specifically or generically different from those which had been delineated by Dalman, Murchison, and other authors who had described the older fossil types. After the Devonian fossils (for many years the opprobrium of the lower palæozoic series) were removed to their proper place in the palæozoic system, there was no longer the shadow of a difficulty in defining the leading palæontological characters of the lower palæozoic rocks. The real and only difficulty was in defining the number and sectional place of their subordinate groups. Their upper groups had been admirably determined in the "Silurian System." But their lower groups were, in that system, either not defined at all, or defined by a reference to local sections which have been proved erroneous. My only hope (in 1842–1843) was—that, through the able assistance of my friend Mr. Salter, I might establish, in the field, a series of fossil groups that would enable me to split up the great Bala and lower Cambrian series into separate stages resembling those of the true "Silurian System." In this attempt we failed. But this failure did by no means prove that there was not a great Cambrian series below the defined groups of Siluria. It did, however, prove—what had often been urged before—that the word *system*, as applied *palæontologically* to the collective groups of Siluria, had been not merely premature, but erroneous.

Should any one ask, what matters it by what name the Welsh series of rocks may be called, so long as we define the meaning of our terms? I should at once reply that good names are of great consequence. That

* Quart. Journ. Geol. Soc. 1847, vol. iii. p. 170.

above all they ought to be historically just; and that, if geographical, they ought not to involve and perpetuate most palpable geographical contradictions. So far as regards the present controversy, between my friend and fellow-labourer and myself, it resolves itself into this: whether I should retain a true geographical name for a country I have explored and reduced to good order, after the hard and long-continued work of years; or he should throw down its fences, claim it for his own, and, in defiance of geographical propriety, call it Silurian, without the shadow of pretence from any right of conquest over it, or any correct original knowledge of its relations to that Silurian region he had won for himself by a like labour, and to which he had a lawful title, acknowledged, I might say, with acclamation, by every geological school of Europe.

The personal question is indeed a paltry matter; but it does involve a very important principle. Philosophical names are not to be given rashly; and premature names ought to be abolished; otherwise we barbarize our language, and retard the true progress of science. Scientific names are, or ought to be, the abstract representations of the highest conceptions of the human mind; which first dealing analytically with facts, then groups them together synthetically under their most general conception. The analysis of the phænomena comes *first*,—the philosophic names come, or ought to come, *last*. Nor are philosophical names ever unimportant, even in mixed and progressive subjects like our own; for they are the very circulating medium of science; and if our coin be base, our scientific dealings can never prosper. And is it not true that in science, as in other things, names are often all that the greater part of mankind ever care about in their commerce with the world, especially on questions like the present?

On grounds such as these, I contend that the very conception of a *downward development* of the Silurian System into the Cambrian is a contradiction of the ordinance of nature; as, ever since the world began, her *systems* have been developed upwards and not downwards; that the description of such a *downward development* under the word *system* is a most anomalous use of scientific language; and that such a word as *system*, in geology, cannot logically be made use of while the analytical process is going on, and before it has led us to a resting-place on which we may commence the true synthetical process of constructing a system.

I do not assert that the word *system* was *at first* used illogically by my friend; because he, no doubt, at first thought that he had found a good base-line for it. But in this we now know that he was mistaken; and from the moment that mistake was proved, his *system* (as a *system*) was at an end. It was then a mere group of strata, which admitted of no collective name, except so far as it was capable of definition; and the parts of it which were before mistaken and ill-defined must afterwards be referred to some new base-line, and find their resting-place in some new arrangement. But changes of this kind imply also a change of our verbal definitions, or we utterly destroy the symmetry of our scientific language.

My proposed general term—the Lower Palæozoic division of the "Primary System," including the Cambrian Series and the Silurian Series—may at present serve our purpose, until our views become better defined by better knowledge. There is not a single known palæozoic rock of Britain that I have not studied; and this at least I may assert, as the result of this study, that it is from the Cambrian and the Welsh mountains that we must construct our British types: and the phænomena of these mountains are the foundation of everything I have offered in this paper in the way of classification and nomenclature.

Since the extension of the lower Silurian colour over the whole Cambrian series by Sir R. I. Murchison, there has, I know, been a general opinion, that I had made some great mistake in my estimate of the palæontological characters of the Cambrian series; that in using the words Cambrian System, I had supposed that the Cambrian fossils formed an entirely distinct zoological group from the Lower Silurian *. Now this I never once asserted; and, from the first, I knew that the very contrary was the case; and it was this knowledge which made me many times in this room object to any strict palæontological use of the word *system*, when applied to Cambrian and Silurian rocks. Although my great Welsh series of rocks and fossils was inaccessible to myself until my new museum was opened for the reception of a vast, and till then unapproachable, collection, yet I had in reserve a small series of specimens from Bodean, Snowdon, Moel Hebog, Bala, Meifod, &c.; and these, as well as my field notes and sections, led me to assert, many times, during the discussions in this room, that the word *system*, as used by its author, was not philosophically applied to Silurian rocks which had not, so far as I could discover, either a good physical or palæontological base. Turn, for example, to the Proceedings (May 1838, vol. ii. p. 679), where, writing of the "Upper Cambrian System," I use the following words: This system "commences with the fossiliferous beds of Bala, includes all the higher portions of the Berwyns, and all the slate-rocks of South Wales which are below the Silurian System."... "Many of the fossils are identical in species with those of the lower division of the *Silurian System*, nor have the true distinctive zoological characters of the group been well ascertained." In the same page I add as follows: "At the north end of the Berwyn chain it" (the *Upper Cambrian System*) "appears to pass by insensible grada-

* This error regarding my own meaning, whenever I made use of the words *Cambrian System*, originated, I doubt not, in the writings of my friend, after he had detected his sectional mistakes, and began to change his own views respecting the relations of his Silurian rocks to the great groups which he had placed below them. Thus, when he tells me (Quart. Journ. Geol. Soc. 1847, vol. iii. p. 173) that "the recognition of a Cambrian System has been considered to be exclusively dependent on the discovery in it of a peculiar type of *life* distinct from that formerly described as Silurian," he writes in direct contradiction to his own interpretation of phænomena made, along with myself, in the field (in 1834), and in apparent contradiction to various passages of his great work; and he now endeavours to saddle me with a *technical* meaning of the word *system* which I never once made use of, and *against* which he had heard me enter my protest *long before* there was a word of controversy between us.

tions into the lower division of the Upper System (the *Caradoc Sandstone*)." Again, in the Proceedings (Nov. 1841, vol. iii. p. 548) I gave the same definition of my *Upper Cambrian group*, and added: "Many of the fossils are identical in species with those of the lowest divisions of the *Silurian System*."

Again, in the next page (p. 549), I give a list of Snowdonian fossils, some of which I collected in 1831. The list was named by Mr. Sowerby the year before Mr. Salter had become my fellow-labourer; and in 1832 I had at least two species of *Orthis* from Snowdon, which I believed identical with two Bala species. Lastly, I will quote the third edition of the Syllabus of my Cambridge Lectures, which was drawn up in 1836 and published very early in 1837, and therefore appeared two years before the publication of 'The Silurian System.' Describing the Upper Cambrian rocks, I used, in this Syllabus (p. 51), the following words: "Associated with them are calcareous slates. *Corals, Encrinites, Trilobites, Orthoceratites, Orthis, Producta, Spirifer*, &c. Many shells of the same species with those of the *Lower Silurian* rocks." Again, in the same page, I affirm, "that the Bala limestone contains *Bellerophon bilobatus, Producta sericea*, and several species of *Orthis, all of which* are common to the *Lower Silurian System*." This third edition of my Cambridge Syllabus was withdrawn from publication in 1840, in consequence of the new palæozoic arrangements become necessary by the introduction of a Devonian series. But the extracts from it above-given, as well as the quotations from our Proceedings, however unimportant in themselves, do bear upon my present question, and prove what I am now asserting,—that I never presumed to separate, palæontologically, the Cambrian from the lower Silurian rocks. If their fossils were of the same general type, the fact would only prove that Sir Roderick's "Silurian System" never was a system in the sense in which he had expounded it; but the fact would by no means prove that he had any right to make good his system by extending it over a province already legitimately occupied, and over which he had no personal claims whatsoever.

On this point I may conclude my remarks, by affirming that my argument is greatly misrepresented by Sir R. I. Murchison *, when he recommends me to abandon the term Cambrian System as applied to the physical groups of North Wales, because such name was used before their fossil contents were known. His advice, whatever may be its worth, is founded in mistake, and obliviousness as to some facts we studied together in the field; and he has little reason to fix on me his own meaning of the word "System," which I never believed correct, and against which I have, as above stated, very often protested in the former discussions of this room.

In 1834, when I, for the last time, met my friend in Wales, that we might compare notes and determine the limits of our respective surveys, he made no difficulty in excluding the Bala limestone (in spite of its fossils) from his "System," and this was done on the supposed evidence of sections. The fact of this exclusion proved that

* Quart. Journ. Geol. Soc. vol. iii. p. 175.

the author *then* thought the evidence of sections necessary to his "System," and that it did not necessarily include every group with Silurian fossils. At that time the important point between us was to determine the limits of our respective sections. He afterwards shifted his ground of classification altogether, but on principles not communicated to myself; and ended by demanding from me a proof that my Cambrian series contained a group of fossils entirely distinct from those of his lower Silurian rocks. He required of me what I had shown him to be impossible before his System had a name. As to the palæontological relations of the Cambrian groups, my views, though expanded during the progress of discovery, never underwent any fundamental change. This progress did, however, prove that the word *system* was, from the first, applied by the author incorrectly to his "Silurian" groups. I worked upwards through the whole Cambrian and Silurian series: my friend worked downwards into the upper part of the Cambrian series, and there came to a fault. There was an undoubted overlap in our ascending and descending sections, producing no small confusion, but this confusion was simply caused by his own mistakes and not by mine: yet is this confusion, on the scheme of my friend, to end by subordinating Cambria to Siluria—by a system of grouping, in the upper part of which the spirit of subdivision is carried, perhaps, to excess, while in the lower part all subdivision, based on good sectional evidence, is discarded—by making more than 20,000 feet of strata the equivalents of one "Silurian" group! No power on earth can stereotype and perpetuate a nomenclature so utterly incongruous,—one part simply geographical and sectional,—the other part neither geographical nor sectional; but evolved through a *downward development* which is out of nature, and strikes at the root of every principle of philosophical arrangement. We may, no doubt, analyse the successive deposits of a new country in the descending order, and this may sometimes be the very best method. But when we proceed to systematize the deposits and give them names, we are absolutely compelled to reverse the process; otherwise we build without a foundation, and violate the historical development of nature.

My friend and opponent tells me (*loc. cit.* p. 173), that, *before his Silurian System was fixed*, foreign geologists had applied the term "greywacke" indiscriminately to the Devonian and other palæozoic groups. This is very true. The upper Silurian groups *were fixed* on right principles, and this was a very great boon to geology, and soon led, almost by a philosophical necessity, to the fixation of the Devonian series. But the lower Silurian groups were *not fixed* by the author. His nomenclature was premature, and his base-line was sectionally wrong; and, so far from leading to discovery, it retarded the progress of palæozoic geology for, I believe, not less than ten or twelve years.

I accept at once the canon, "that a good nomenclature can only be based on a conformity of successive and similar organic remains *." For we all admit that a good geological nomenclature is, not simply

* *Loc. cit.* p. 173.

a zoological question, but a question depending on the *evidence of sections, aided by the evidence of fossils*. But where was the author's "conformity of succession," proved by the evidence of good sections, among his lower Silurian rocks? He mistook the relations of these rocks to the Cambrian groups, and his fundamental general sections are wrong in details as well as in principle. What then becomes of the lower Silurian rocks, if their names are to be tested by this canon? I can conceive but one rational answer to this question.

Again (*loc. cit.* p. 170), he tells us that "his nomenclature is founded on the principle of *strata identified by their fossils*." If we are dealing with elements of which we know the limits, the principle stands good; but while we are dealing with the nomenclature of a new series, of which we have not made out the limits, the application of this principle would be nothing better than a specious fallacy. I should give an illustration of this fallacy had I attempted to call the whole Cambrian series by the name of Bala Limestone; and the author has given us a frequent illustration of it in identifying the same series with the Llandeilo flagstone. Were we to take the palæontological evidence *alone*, and sink all other means of classification, I believe that the massing of all the Lower Palæozoic Division of my Tabular View (see p. 147) under one system of animal type would turn out to be a palæontological blunder. There is a magnificent development of this Lower Division in North America capable of separation into two very distinct collective groups (like the Cambrian and Silurian groups of the Tabular View), the upper of which is (if I am rightly informed) sometimes unconformable to the lower; and although many species may be common to the two collective groups—especially near their junction—yet the species most abundant in, and most characteristic of, the lower are not found in the upper; nor are the most abundant and characteristic species of the upper ever found in the lower. If so, the development of animal types, from the early dawn of a living world, appears to have been carried on in North America in strict analogy with the development now exhibited in the British Isles; and I am greatly mistaken if the scheme of development, given in the Tabular View, be not more acceptable and intelligible to the American Geologists than any other scheme of arrangement of the British rocks which has yet been published.

Out of this Lower Palæozoic division M. D'Orbigny makes *two palæontological systems*; M. Barrande did the same virtually, though not in words; and if I may judge from my Cambridge collection, as arranged by Professor M'Coy, there is as wide a separation between the Silurian and Cambrian groups, as between any two consecutive members of the whole Palæozoic System of the Tabular View. But I do not rest my conclusions upon this last statement; but rather upon such evidence as I have given in the previous pages of this paper, and especially on the broad fact—that my original Cambrian sections were right in principle; while Sir R. I. Murchison's sections were, in the exhibition of his lower groups, wrong in principle and conception.

So long as my friend worked upon the plan of Dr. William Smith

and the geologists of his school—combining sections with fossils, and never using fossil evidence as definitive until his physical groups were well in hand—he made no mistake in principle; his system was worked out with consummate zeal and skill; and in the true typical country of Siluria he left but few gleanings for those who followed him. But on leaving his true typical Silurian region his good fortune left him; and in following down the lowest beds of his system, he hit off, both to the north and the south, a wrong type for the Caradoc sandstone. It might be called a small mistake to have regarded the Meifod beds as typical Caradoc sandstone, and to have figured some of its fossils as characteristic specimens of that group. But, small as was the mistake, it led Mr. Bowman, Mr. Sharpe, and myself into a very wrong interpretation of certain sections in North Wales. To them the mistake was of small moment, as it only led them to give a wrong name to a single fossiliferous group: but to me the mistake was far more mischievous; as it led me to take my very keystone from an arch I had constructed on right principles and after the hard and successful labour of two summers; and it threw into confusion the whole plan on which I had constructed my upper groups. But this fact surely proves, how unmeaning fossils are in determining the true, detailed, geological sequence of any new country without a continual check from sections.

But the great mistake of the "Silurian System,"—and so far as regards its effects upon my own work, the most perplexing mistake,—was the placing the Llandeilo group *over* the upper Cambrian series of North and South Wales; and until this mistake was corrected, all further progress in arrangement and nomenclature of the older paleozoic groups became impossible. Near the end of the summer of 1843 I found it impossible to separate the Bala limestone from the calcareous groups of Glyn Ceiriog and Meifod; but, if the Meifod group were, on the interpretation of Sir R. I. Murchison, a typical form of the Caradoc group, it followed that the Bala limestone must also belong to the true Caradoc group. Nor was this all,—a great group over the calcareous slates of Bala, which I had before described as upper Cambrian, was called, both by Mr. Salter and Mr. Sharpe (on supposed fossil evidence), upper Silurian. Again, on like evidence, Mr. Salter was compelled to call the (Caradoc) group under the Denbigh flags upper Silurian. If all this were true, I knew well, on the evidence of my own sections in South Wales, that a considerable portion of the undulating beds in that part of the Principality, as well as the gritty beds in the highest trough of the Berwyn chain, must also be called upper Silurian. As before stated, these conclusions were put to the test by myself in 1836, and found to be erroneous. I then had a demonstrative proof that the Bala limestone was not Caradoc—that the Meifod beds were wrongly classed and named,—and that the geological relations of the Llandeilo group were mistaken by the author of the 'Silurian System.'

It was during the interval of uncertainty, between 1843 and 1846, that I was willing to modify my nomenclature,—believing, during that interval, that my upper Cambrian group must disappear; inas-

much as I knew that the Silurian groups were well made out in unequivocal sections to the base of the Caradoc sandstone; and, therefore, as far as that base descended, that the author had an apparent right to claim every rock of North Wales as a member of his own system. But in the published map, prepared by Mr. Warburton, and not seen or revised by myself, my concessions, as above-stated, are greatly mistaken and greatly misrepresented. When all previous doubts were cleared up in 1846, I returned, as a matter of course, to my old nomenclature; for my original sections of North Wales were right, and my nomenclature was natural and true. Meanwhile (and, strange as it may seem, unknown to myself, for, I believe, nearly three years) my friend had extended his Silurian colours to the western coasts of Wales; and hence the origin of whatever words of amicable controversy have ever passed between us.

What I finally affirm is this,—that the whole scheme of my sections (from the very first which I exhibited at Oxford in 1832, and at Cambridge in 1833) was physically, and (so far as my fossils went) palæontologically right—that I was never led into a false or incongruous classification by any section of my own—that in every instance in which I was led into hypotheses in any way incongruous with the order of superposition indicated by my sections, I was so far led into positive error—and that every instance of doubt or wavering on my part arose, at the time, from a belief (I now know to have been erroneous) that the author of the 'Silurian System' could not have mistaken the relations of his normal lower types, but that I might, perhaps, have mistaken the true relation of one or two of my highest Cambrian groups.

All doubt on this head is now at an end, and I continue to place my *Upper Cambrian series* (a little extended, not from any change of my sections, but merely as a matter of symmetrical convenience, and termed the *Bala group*) where I placed it in 1833. The relations of the Bala limestone to the groups above it and below it are not, in this scheme, mistaken; nor was I ignorant of its fossils *before* the publication of the 'Silurian System,' as I have proved by previous quotations.

It is true that the Llandeilo flagstone is, on this scheme, removed out of the Silurian groups; for the Llandeilo flagstone is the undoubted equivalent of the Bala limestone. It is also true that my friend has published a magnificent series of fossils from the Llandeilo flagstone, including therein a group he has mistaken for Caradoc sandstone. But no published group of fossils entitled the author, on *his own canon* of classification and nomenclature, to claim the Llandeilo group as his own and to give it a permanent name, until he had made out its relations to the groups above it and below it; and in this last condition he entirely failed. The author has, in his great work, published many admirable details respecting the development of the Llandeilo groups among the Plutonic rocks of Shropshire and other tracts of country on the frontiers of Wales, and for these details, and the good theoretical suggestions arising out of them, he is entitled to the lasting gratitude of this Society. But none of these details

touch upon the real question in debate. They do not give us the means of establishing the relations of the Llandeilo group to the groups above it and below it, in any general sections which define the lower Palæozoic series. This fatal objection does not apply to the Bala limestone; which becomes a true typical group, and is capable of receiving a permanent name, because its place is well defined in the grand development of the older Palæozoic series of Wales; and on that account it obtains its place in the Tabular Section.

I accept the interpretation of the structure of Wales as given in the great map, published under the direction of Sir Henry de la Beche, which is one of the noblest works of its kind that has appeared since Geology was a science. In this map we have the superficial delineation of the true system of Siluria perfectly represented in its most minute details; and the authors have, for the first time, laid down the range of the Caradoc group in a manner that is intelligible and complete. But they have given the name "Lower Silurian" to all the vast series of rocks in Wales, which are below the Caradoc Sandstone. I do not believe that their authority, great as it is, can permanently establish a name that is geographically incongruous and historically unjust. Passing over the strange geographical and geological incongruity of merging all Cambria in Siluria, although the groups of the former include the whole lower palæozoic series, and the groups of the latter country include only the upper members of that series,—and passing over the palæontological objection based on the assumed fact that there are two systems of animal life in the upper and lower divisions of the same great series sufficiently distinct to require separate zoological names,—dismissing these considerations from the question, I affirm that the name "Silurian" given to the great Cambrian series below the Caradoc group is historically unjust. I claim this great series as my own by the undoubted right of conquest; and I continue to give to it the name "Cambrian" on the right of priority, and, moreover, as the only name yet given to the series that does not involve a geographical contradiction. The name "Silurian" not merely involves a principle of nomenclature that is at war with the rational logic through which every other palæozoic group of England has gained a permanent name, but it also confers the presumed honour of a conquest over the older rocks of Wales on the part of one who barely touched their outskirts and mistook his way so soon as he had passed within them.

I claim the right of naming the Cambrian groups, because I flinched not from their difficulties, made out their general structure, collected their fossils, and first comprehended their respective relations to the groups above them and below them, in the great and complicated palæozoic sections of North Wales. Nor is this all,—I claim the name "Cambrian," in the sense in which I have used it, as a means of establishing a congruous nomenclature between the Welsh and the Cumbrian mountains, and bringing their respective groups into a rigid geological comparison; for the system on which I have, for many past years, been labouring is not partial and one-sided, but general and for all England.

DONATIONS

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American Association. Proceedings, Fourth Meeting, August 1850.

———— Journal of Science. Second Series, vol. xii. no. 36.

Architect Journal for November.

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Bordeaux, Société Linnéenne de, Actes. Tome xvii. livr. 3.

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Glasgow Philosophical Society, Proceedings. Vol. iii. no. 3.

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Philosophical Magazine for December. *From R. Taylor, Esq., F.G.S.*

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Washington, Smithsonian Institution. Smithsonian Contributions to Knowledge, vol. ii. Fourth Annual Report, 1849. Ephemeris of Neptune for 1852. Report on the Discovery of Neptune, by B. A. Gould, Jun. Notices of Public Libraries in the U.S. of America, by C. C. Jewett.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

On the Meaning of the term "Silurian System" as adopted by Geologists in various countries during the last ten years.

By Sir Roderick Impey Murchison, F.R.S., G.S., Member of the Academies of St. Petersburg, Berlin, and Copenhagen; and Corr. M. Inst. France.

[Read June 16, 1852.]

Introduction.—As in the last memoir printed in the preceding number of this Journal* my old friend Professor Sedgwick has animadverted upon some of my proceedings in establishing the Silurian System and in afterwards extending its application to British tracts beyond those in which it was originally formed,—I now offer, with the permission of the Council, a reply, which shall be very brief, and which, in vindicating my scientific credit, will be little more than a reference to documents published in successive years on this subject. Being perfectly sure that, whatever may have been the strength and pungency of his expressions, Professor Sedgwick had no intention to hurt my feelings, I am also certain, that he will be pleased that I thus have an opportunity of explaining what I consider to be the history of the origin and final establishment of my own Silurian classification.

* *Vide supra*, pp. 136 *et seq.*

Historical Retrospect.—(1831.) In the year 1831 Professor Sedgwick and myself commenced, but without any concert, our respective surveys, he in North Wales, and myself along the Welsh and English borders. In that year he published no notice of his observations; but on my part, being then President of the Geological Society, I laid before the first meeting of the British Association at York (Sept. 1831) a coloured geological map representing the succession of what I then termed the "Transition Rocks, Old Red Sandstone, and Carboniferous Limestone on the borders of Wales*." My contemporaries (Mr. Greenough, Professor Phillips, and others) who were present will recollect, that I then explained the discovery of an infraposition of certain beds of fossiliferous greywacke to the lowest member of the Old Red Sandstone, and described their general range from the banks of the Wye to those of the Teme near Ludlow, or to that tract where the Rev. T. T. Lewis afterwards rendered me signal assistance. The discovery was made in consequence of a resolution of my own to endeavour to work out, if possible, a descending order beneath that geological horizon to which previous researches had carried it. This was the origin of a series of labours, the results of which were in successive years communicated to the Geological Society and registered in its Proceedings, and which ended, in the year 1835, in my proposal of the "Silurian System."

(1832.) Professor Sedgwick's first communication to the public on the structure of North Wales was made to the British Association at its second Meeting in 1832, and is entitled "A Verbal Account of the Geology of Caernarvonshire," which is reported in a few lines of type, in which no allusion is made to an order of succession in relation to any known stratum, nor to rocks characterized by any organic remains.

(1833.) In the years 1833 and 1834 Professor Sedgwick published nothing, as far as I know, on the subject of Wales, whilst in that period I produced before the Geological Society several memoirs, detailed sections, many sheets of the Ordnance Survey coloured by myself in the field, and copious organic remains, by which in February 1833 a first general view was adopted of *four fossiliferous formations*, underlaid by a great mass of unfossiliferous greywacke†.

(1834.) In January 1834 the previous view was sustained, improved, enlarged, and corrected in some details, the formations beneath the Old Red Sandstone being termed in descending order Ludlow Rocks, Wenlock and Dudley Rocks, Horderley and May Hill Rocks (afterwards named Caradoc), Builth and Llandeilo Flags, the whole underlaid by the unfossiliferous greywacke of the Longmynd‡.

Let me here remark, that this my earliest corrected classification, and before the word "Silurian" was applied to it, is what has been eventually sustained as the true order of nature in many parts of the world as well as in Britain.

(1835.) Having extended my researches from the counties of

* Report of the British Association, vol. i. p. 91.
† Proceed. Geol. Soc. vol. i. p. 470 *et seq.*
‡ Proceed. Geol. Soc. vol. ii. p. 11.

Salop (Shropshire), Montgomery, and Hereford, through those of Radnor, Brecon, and Caermarthen, and having recognized an outcrop of all the fossiliferous strata above-mentioned, as surmounted by the Old Red Sandstone, I was urged by geologists at home and abroad to give a distinct name to this whole series of fossiliferous beds. Hence the word "Silurian," as propounded early in the year 1835; the *System*, as I then termed it, being divided into Upper and Lower groups*.

Had I never published a single document beyond the memoirs already mentioned, no one could have disputed my right in the world of science to sustain a nomenclature and classification which was entirely my own. I had, in short, propounded a natural system, which.

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Oral communications made by Sir Roderick Murchison and Professor Sedgwick at the third meeting of the British Association (Cambridge, 1833) have, through inadvertence, not been referred to. These communications are, however, merely reported in a few lines of type, and simply state that the authors explained the leading features of their respective regions; Professor Sedgwick pointing out the relations of his tract to that described by Sir R. Murchison, of which the latter exhibited coloured maps and sections. (See Reports, Brit. Assoc. Adv. Sc. vol. iii. Proceedings, p. xxxiii.)

Quart. Journ. Geol. Soc. vol. viii. Part I.

On one occasion (in 1834) I crossed the assumed limit in the Berwyn Chain, travelling by the high-road, in his company, to look for a moment at the Bala limestone, which I then believed to plunge under those true Llandeilo flags with *Asaphus Buchii* which I had recognized on the east flank of that chain. This idea of the order of infraposition has proved to be entirely erroneous, and if I "lost my way" in going downwards into the region of my friend, it was under his own guidance. I am answerable only for Silurian and Cambrian rocks described and drawn as such *within* my own region.

Not seeing in that hurried visit any of the characteristic Llandeilo Trilobites in the Bala limestone, I did not then (1834) identify that

* See Philosophical Magazine, New Ser. vol. vii. p. 46 *et seq.*
† Proceed. Geol. Soc. vol. ii. p. 226.
‡ Quart. Journ. Geol. Soc. vol. iii. p. 161.
§ Report of the British Association, August 1835, Trans. Sections, p. 59.

rock with the Llandeilo flags, as has since been done by the Government Surveyors; nor does it ever appear to have occurred to Professor Sedgwick that these were beds of about the same age as those which we had seen together on the east flank of the Berwyns, on the banks of the Twrch, where they were recognized by me as "Llandeilo Flags." But having afterwards ascertained that several species of Orthidæ which occur in the Bala rock were common both to the Caradoc and Llandeilo formations, I specially stated, four years afterwards, in publishing the 'Silurian System' (1838), "As these shells abound also in the Lower Silurian rocks, it would seem that as yet no defined line of zoological division can be drawn between the Lower Silurian and Upper Cambrian groups, and that, as our knowledge extends, we may probably fix the lowest limit of the Silurian System beneath the line of demarcation which has for the present been assumed*."

In reference to the argument about a "base-line," as employed by Professor Sedgwick, I must state that in the whole 'Silurian System' the term "base-line" is never once applied to these rocks. I had quite labour enough within my own region, without being made responsible for the accuracy of the western boundary of my original map of 1830, that separated Siluria from Cambria; but which ten years ago I abrogated, as being wholly inaccurate. That line was, I maintain, a boundary merely between one region whose contents had been worked out and published, and another whose fossil contents were unpublished and therefore unknown.

The simple question, then, which every practical geologist has long ago answered in the negative, is this, Was the Cambrian system ever so defined, that a competent observer going into an uninvestigated country could determine whether it existed there? That it was never so characterized is demonstrated by the successive publications of Professor Sedgwick himself, to say nothing of the inferences of every one of our contemporaries who have examined countries at home or abroad in which such rocks occur. For wherever well-known Lower Silurian fossils occurred in such countries, the tracts so typified have necessarily been called Silurian.

(1836–38.) I have already stated, that during the establishment of the Silurian System and up to the period when it was so named, Professor Sedgwick published nothing on the subject; and, although he refers to a Cambridge Syllabus of Lectures drawn up in 1836, and issued early in 1837, wherein he uses the word "Cambrian" (I have referred above also to the communication made at the Dublin Meeting of the British Association), it is only in 1838 that we meet with the first published abstract of a real memoir, his "Synopsis of the English Series of Stratified Rocks inferior to the Old Red Sandstone"†; followed in 1841 by the "Supplement to a Synopsis of the English Series of Stratified Rocks inferior to the Old Red Sandstone‡." For the indistinctness of the author's views on those occasions respecting the fossil contents of his Cambrian rocks (two or

* 'Silurian System,' p. 308. † Proceed. Geol. Soc. vol. ii. p. 675 *et seq.*
‡ Proceed. Geol. Soc. vol. iii. p. 541 *et seq.*

three species of which only are mentioned, not one being figured), I refer to his own words*.

At the same time there came out (for the work was really issued in 1838, though 1839 is on the title-page) my 'Silurian System' with its detailed evidences and figures, by which, both at home and abroad, so many regions have been assimilated to the Lower as well as to the Upper Silurian tracts therein described. So far for the priority of our respective publications and for the nature of them.

I had, in a word, completed in 1838 the illustration of a natural system which had been worked out by fossil evidences in 1833, 1834, and 1835, whilst in the same years Professor Sedgwick had neither shown the real physical relations of his rocks to my already well-known types, nor had he published any descriptions of fossils by which his so-called "Cambrian System" could be recognized as entitled to a separate name.

(1840–43.) Unwilling to encroach upon the Cambrian region, and believing, from the delay of my friend (his fossils were even then unexamined), that much time must elapse before the rocks of so complicated, contorted, and difficult a country as North Wales could be properly classified, I resolved to test the value of my own labours by an extensive appeal to foreign countries, and in consequence visited Russia accompanied by M. de Verneuil in 1840 and 1841, where Count Keyserling joined us. The results were so palpable, that, being again President of this Society, I put forth, in the most prominent and public manner in the first pages of the Discourses of 1842 and 1843, as printed in the Proceedings†, the expression of my conviction, that the Lower Silurian rocks were the oldest fossil-bearing group; adding my belief that the same rocks ranged over nearly all North Wales.

I specially refer every student in geology, who may not have followed the process of induction by which the Silurian classification was thus applied generally, to the pages of my Discourse of 1842 which commence under the heading of 'Palæozoic Geology,' and in which the Silurian, as surmounted by the Devonian and Carboniferous, is shown to be the oldest fossiliferous system‡. My general view was founded on what I saw in the north of Europe and in Bohemia, and my distinct and final application of it to North Wales was made in 1843 in consequence of a traverse across that region with Count Keyserling, when we found the Lower Silurian fossils in and around Snowdon. Hence the publication of my small general Map of England, executed at the request of the Society of Useful Knowledge, in which the erroneous line of demarcation between Siluria and Cambria was obliterated.

In these proceedings, which, in a British geographical sense, so vastly extended the application of the Silurian system, and which showed why the provisional cartographical boundary between Siluria and Cambria was expunged, I simply but courteously explained, that a broad appeal to nature in foreign countries, followed by a traverse

* *Op. cit.* p. 554. † Vols. iii. and iv.

‡ Proceed. Geol. Soc. vol. iii. p. 640.

of North Wales, had led me by a process of induction, and not by any "rash generalization," to adopt these views. In my Discourse of 1843 I used these words in reference to the last publication of Professor Sedgwick himself:—"The hope, however, which was entertained by my friend, of finding these vastly expanded lower members characterized by peculiar groups of fossils has been frustrated, and, whatever may be the thickness of the lowest palæozoic division, he now fully admits, that zoologically it is from top to bottom a Lower Silurian Series*."

(1845.) Having ascertained that there was a true fossiliferous base in Scandinavia, Bohemia, and other countries, I then wrote (1845) those earlier chapters in 'The Geology of Russia and the Ural Mountains,' to which my friend makes no allusion, though in them the general order from true "base-lines" was first given, from an unfossiliferous bottom, through the Lower and Upper Silurian and overlying palæozoic deposits, to the Permian (then so named by myself) inclusive. This was no "downward development," but an original and clear exposition of a true, natural ascending order from a fossiliferous base-line.

This being done, and the North American geologists having adopted the same views, it still remained a desideratum in our own country to ascertain, by physical and geological proofs, if the Cambria of Sedgwick was what I had suggested, *i. e.* essentially nothing but Lower Silurian.

In North Wales Mr. Davis made the first approach to the ascertainment of a base of what he termed "Silurian Rocks," by the discovery (November 1845) of the now well-known Lingula-beds of Tremadoc†, the true physical position of which, in reference to the underlying unfossiliferous grits of Barmouth and to the overlying series replete with common Lower Silurian fossils, was subsequently carried out by Professor Sedgwick and the Government Geological surveyors.

(1846.) In all his publications in the Proceedings and the Journal of the Society, up to the early part of 1846, Professor Sedgwick made no objections to the sense which I had so prominently attached to the term "Silurian" in 1841, 1842, and 1843. He had then even himself so applied my nomenclature to the rocks of Cumberland and Wales, that Mr. Horner, as President of the Society, after a full exposition of the extension of the original Siluria, thus spoke in his Anniversary Discourse of 1846‡:—"Since the discovery of the Silurian key, he [Professor Sedgwick] has been enabled to make a clear and intelligible outline of the history of these regions, which, for a long time, geologists seemed to shrink from all attempts to understand."

In truth, Prof. Sedgwick himself had up to that time invariably appealed to my *Lower Silurian* as well as to my Upper Silurian division and their respective fossils as his guides in elaborating the fossil groups of Cumberland and Wales. How, therefore, could I, or

* Proceed. Geol. Soc. vol. iv. p. 74; the same opinion was previously expressed (1842) vol. iii. p. 549.

† Quart. Journ. Geol. Soc. vol. ii. p. 70. ‡ *Ibid.* vol. ii. p. 162.

any one, suppose otherwise than that he had then agreed *ex necessitate rei* to the classification I had proposed, and which all my contemporaries had adopted?

The present controversy, which on my part I now close, began at the end of the year 1846, or eleven years after the promulgation of the Silurian System in England, and four years after it had been extended and generally adopted. In the Supplement to his memoir of 1846, "On the classification of the fossiliferous slates of Cumberland, Westmoreland, and Lancashire," Professor Sedgwick put forth opinions which I was compelled to oppose; because I foresaw, that if a fossiliferous Cambrian group were to be formed by the abstraction of a portion of the Lower Silurian, and the Wenlock shale thrown into the Lower Silurian as a sort of make-weight to enlarge the Caradoc, I might very soon be called upon for a further concession, and be asked to abrogate entirely the lower half of the system: this is literally what has followed.

To that memoir* I therefore replied at the conclusion of a paper on the Silurian rocks of Sweden†. To another and more elaborate memoir‡ by my friend I also replied§ in the paper entitled "On the meaning originally attached to the term 'Cambrian System,' and on the evidences since obtained of its being geologically synonymous with the previously established term 'Lower Silurian.'"

To these two memoirs I refer young geologists for all that I could say and which I then thought settled the question at issue. Five years have elapsed during which I have published nothing on this controversy. In the mean time, however, authors who have written on palæozoic geology, in every part of the world, have either gone on with, or adopted my terminology; and, what is most gratifying to me is, that the Government Geological Surveyors have definitively taken the same course, and have in accordance coloured all their maps and sections, and have so named all the fossils of the great Museum presided over by Sir Henry de la Beche. All the fossils of the region of Cambria or North Wales (down to the Lingula-beds inclusive) are now classified as Silurian.

But this band of able men have done much more. They have sustained the value of my chief original *sections*. They, having also used my keys, have decided, after years of hard labour in the field, that the whole of the fossiliferous strata of North Wales are repetitions, by undulation, of certain Lower Silurian strata first described by me in 1834, and of which detailed coloured sections were finally published in 1838. Showing that my original unfossiliferous base, the Longmynd of Shropshire, offers a more copious development of the unfossiliferous rocks to which they now restrict the term "Cambrian," than any of the oldest slaty masses of North Wales, they affirm, that, overlying such unfossiliferous greywacke on the west, and in the order in which I have represented in coloured sections ('Silurian System,' pl. 32. figs. 1, 2, 3), the Lower Silurian schists and quartz-rocks of the Stiper stones and the Llandeilo series of Shelve

* Quart. Journ. Geol. Soc. vol. ii. p. 106 *et seq.* † *Ibid.* vol. iii. p. 1 *et seq.*
‡ *Ibid.* vol. iii. p. 133, Dec. 1846. § *Ibid.* vol. iii. p. 165, Jan. 1847.

are precisely represented, after numberless undulations, by the oldest fossil-bearing sandstones and schists of North Wales.

That several of my sections, where they traversed the boundary-line between the Siluria and Cambria of my original map, are erroneous, as my friend states, is necessarily true. Yet even here, the main physical lines are for the most part faithful to nature. Thus, in Montgomeryshire on the east slope of the Berwyns, there are schists which conformably underlie true "Llandeilo flags" as represented by me*; but these, instead of being any longer called Cambrian, have been shown by the Government Surveyors to be part and parcel of the Llandeilo formation. The same authorities have further shown, that the overlying and undulating masses of sandstone, which from many of their fossils I had termed Caradoc sandstone (Meifod), are really the upper members of the now more accurately defined Llandeilo group. I may here observe, that the unconformity between the Llandeilo and the Caradoc, which Ramsay and Aveline† were the first to trace through certain counties, is after all a local phænomenon; for the same authors have ascertained, that, in the vicinity of Bala itself, the equivalent of the Caradoc sandstone overlies conformably the limestone which is identical with that of Llandeilo ‡. And thus I am led to adhere more than ever to my old and simple classification of "Upper and Lower Silurian" rocks, and not to divide the latter into two groups, particularly when it is now ascertained that so very many characteristic species are common to all the lower parts of the series, whether sandstones, limestones, schists, or slates. Caradoc and Llandeilo may be conveniently separated in certain tracts, but, as respects general views, they constitute one natural group.

Again, my old sections in Pembrokeshire, such as that near Llandewi Felfrey §, which also indicate lower schists conformable to Llandeilo limestone, are correct, if the name of Cambrian be omitted. In other sections ‖ along the original frontier there are even strata coloured Cambrian which *overlie* the Lower Silurian, proving that at all events I endeavoured to draw fairly what I saw, though I did not then attempt to solve such enigmas.

With these physical obscurities along the frontier-line I never grappled, because they led me away from a region where all was comparatively clear into a highly complicated tract, the survey of which Prof. Sedgwick had undertaken: and now that the Government Surveyors have shown that our mutual boundary-line was a mere hypothesis, and that the so-called "Cambrian" is absolutely composed of undulations of my Silurian rocks, there is no question at issue.

I trust that on reflection my friend Professor Sedgwick will see,

* 'Silurian System,' pl. 29. fig. 9.

† Quart. Journ. Geol. Soc. vol. iv. p. 294 *et seq.*

‡ Such local unconformity can indeed never be admitted as a ground for breaking up any natural group. In parts of South Wales, for example, one portion of the coal is unconformable to another; and in Brittany, the great break, differing essentially from that in the Silurian rocks of Wales, which is above alluded to, occurs beneath the Llandeilo or lowest Silurian strata, and between these and the unfossiliferous slates or Cambrian.

§ 'Silurian System,' pl. 35. fig. 5. ‖ *Ibid.* pl. 34 fig. 3.

that if there be errors in so large and diffuse a work as the 'Silurian System,' I ought not in fairness to be judged in 1852 by errors put forth in 1835–38. How progressive our science is, he has himself shown in several of his memoirs, in which, using the clue afforded by the fossiliferous rocks of the Silurian System, he unravelled and classified the older rocks of North Wales and Cumberland. In justice also he will not, I am sure, ignore what was done by myself and associates in foreign countries, where we traced a "base-line" on a great scale. Ten years have elapsed since I applied that view to Britain, and I claim, therefore, to be judged only by the final and extended Silurian System which was promulgated in 1842, and not by every detail in the original work of 1838; though I am well pleased to find that its general views have been sustained by the researches of the Government Surveyors.

Together with proofs of physical identity, the Naturalists of the Government Survey have satisfied themselves, that the Silurian, though locally divisible into parts and formations, is *one Natural History System*, and as such they have arranged it; showing that a very great number of the species of its fossils are common to its lower and upper divisions. I am further distinctly assured, both by their publications and by many recent communications, that eminent palæontologists of foreign countries are of the same opinion; and in proof of it they have adopted the word "Silurian" as applied by myself during the last eleven years, to the lowest known fossil-bearing strata.

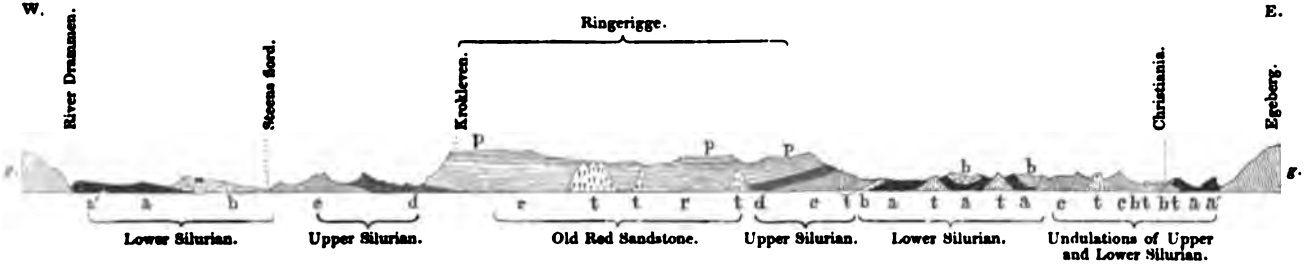
Widely as the Lower Silurian rocks are expanded in North Wales, and interlaminated as they are there with huge igneous masses, they contain no greater number of fossils characteristic of their age, than beds of only a twentieth part their thickness in some other parts of the world. The Silurian rocks of Norway, for example, as copiously laden with fossils as strata of the same age in any other part of Europe, rise up to the east and west from beneath the Old Red Sandstone of Ringerigge, and so occupy the depressions of Christiania and Steensfiord, that both the lowest and uppermost members of the System are repeated in undulations within the space of a mile or two, are perfectly conformable, and utterly inseparable. The accompanying section, which I made in the year 1844, fully explains the phænomena*.

It therefore follows, that if, when Professor Sedgwick formerly examined the rocks of Cambria, he had ascertained by examination that both the strata and the fossils were really the same as what I described as Lower Silurian, and that, in consequence, two distinct

* A rough and imperfect sketch of this important section appeared in the Proceedings of April 30, 1845 (Quart. Journ. Geol. Soc. vol. i. p. 469); and an enlarged and more correct sketch, taken from 'The Geology of Russia in Europe and the Ural,' was inserted in 'Miscellanea' of the second volume of the Quart. Journ. Geol. Soc. (Part II. p. 71). In this position, however, it has escaped notice; and it is here reproduced in illustration of the above remarks on the facts relating to the small development of the rich Upper and Lower Silurian rocks in Norway. —[R. I. M.]

Section across the Territory of Christiania.

Distance about 30 miles.



r. Red Sandstone and Conglomerate = Old Red **Sandstone.**
d. Calcareous flagstones, &c.
c. Coralline limestone and shale (Wenlock fossils) } = **Upper Silurian.**
b. Pentamerus limestone (*P. oblongus*).
a. Schists, flags, and lower sandstone (*Asaphus Buchii* **and many Trilobites**) } = **Lower Silurian.**
a'. Alum schists, with Graptolites, &c.
g. Azoic or gneissose rocks, with old granite, greenstone, **&c.**
p. Rhombic porphyry in the Old Red Sandstone. }
f. **Eruptive** and trappean **rocks of various characters.** }

N.B. The undulations of the beds *a*, *b*, *c*, as seen in nature, are but imperfectly represented in a section of such a reduced scale as the above.

names had been applied to that which is ascertained to be *one natural system*, great disservice would have been done to geological science.

I am now well pleased to find, that, with the exception of my old friend, all my geological contemporaries in my own country adhere to the unity of the Silurian System, and thus sustain its general adoption. In fact, they know that the proposed application of the word "Cambrian" must necessarily cause an alteration of a fundamental character in the nomenclature used in every memoir and work on rocks of this age during the last ten or eleven years; for the Lower Silurian rocks of North Wales so described by Sharpe, Phillips, Davis, and Ramsay, and, finally, so styled in all the Government works by Sir H. De la Beche,—the Lower Silurian of Ireland so named, mapped, and illustrated by Griffith, Portlock, and M'Coy,—and the Lower Silurian of Scotland so expounded and illustrated by Moore, Nicol, Harkness, Salter, and myself—must, according to Professor Sedgwick's project, be changed to Cambrian. Again, the British writers on general geology, Lyell, De la Beche, Mantell, Ansted, as well as E. Forbes and all palæontologists, must alter the names and arrangements they have adopted.

Still more striking would be the revolution as respects foreign countries; for, as Russia, France, Spain, and other regions offer only very slight traces of the Upper Silurian, the System must virtually be there expunged, and the word Cambrian be substituted in all works and maps. The elaborate and valuable monograph of Barrande, 'The Silurian Basin of Bohemia,' must not only have a fresh name, but the whole principle of classification of that able writer, who distinctly affirms that it is one great system of life as of rocks, must also be changed; whilst in America the "system" which Hall and others have so well paralleled with the "Silurian," and the writings and maps of Logan on the Canadas, must all be re-cast and re-named.

I may here say, that I was never so truly gratified as when my contemporary brother workmen (my old friend Professor Sedgwick being one of them) united in recommending me as worthy of the highest British scientific honour; and I specially recur to this point, because the Copley Medal of the Royal Society was bestowed on me in the year 1849, not merely for the publication of the Silurian System of 1838, but also *for its subsequent and extended application to other countries**.

No one more regrets than myself that Cambria should not have proved what it was formerly supposed to be, more ancient than the Silurian region, and thus have afforded distinct fossils and a separate system; but, as things which are synonymous cannot have separate names, there is no doubt that, according to the laws of scientific literature, the term "Silurian" must be sustained, as applied to all the fossiliferous rocks of North Wales.

Lastly, let me say to those who do not understand the nature of the social union of the Members of the Geological Society, that the

* The terms in which the Copley Medal was awarded in 1849 are—"For the eminent services he has rendered to geological science, and for his works, 'The Silurian System' and 'The Geology of Russia and the Ural Mountains'."

controversy which has prevailed between the eloquent Woodwardian Professor and myself has not for a moment interrupted our strong personal friendship. I am indeed confident we shall slide down the hill of life with the same mutual regard which animated us formerly when climbing together many a mountain both at home and abroad.

March 10, 1852.

The following communications were read:—

1. *On the* Upper Tertiaries *at* Copford, Essex. By John Brown, Esq., F.G.S.

Of the geological features of the county of Essex, none are more interesting than its various freshwater deposits, especially those of Grays, Clacton, and Copford. Notices of these deposits have appeared at various times*, and a general description of the freshwater beds and erratic tertiaries of the last-named place forms the subject of the present paper.

The Copford freshwater beds have been for several years extensively excavated to obtain brick-earth, and an idea of the relative position of the beds exposed by these excavations is given by the accompanying section. The clay or "earth" is obtained from three extensive workings, hereafter referred to as the western, eastern†, and southern sections respectively. Other sections of these beds have also been obtained by casual excavations and by borings, to the west and south of the brick-field. This brick-field is about half a mile N.W. of Stanway Church, and lies between the railway and the high road, occupying about five acres. The ground slopes from the high-road northward to the flat marshy ground which is crossed by the railway embankment.

Although the Copford deposit cannot boast of such a long and varied list of fossil Mammalia as those of Grays and Clacton, it is richer in land and freshwater Mollusca; that of Clacton having produced about fifty species, and Grays about forty-five species, while Copford has afforded sixty-nine species, as far as investigations in these deposits have hitherto gone.

In describing the series of beds forming this deposit, we shall begin at the bottom of the section.

* *Grays*, Loudon's Mag. Nat. Hist. 1836, vol. ix. p. 261; Mag. Nat. Hist. N.S. 1838, vol. ii. p. 546.

Clacton, Mag. Nat. Hist. N.S. 1838, vol. ii. p. 163, and 1840, vol. iv. p. 197; Proc. Geol. Soc. 1845, vol. iv. p. 523, and Quart. Journ. Geol. Soc. vol. i. p. 341.

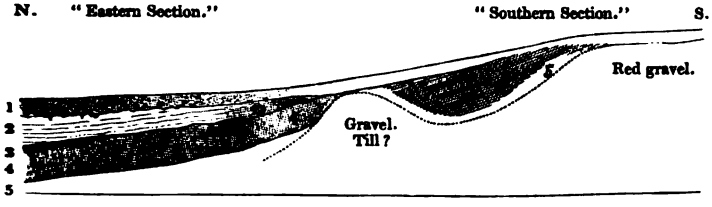
Copford, Loudon's Mag. Nat. Hist. 1834, vol. vii. p. 436, and 1836, vol. ix. p. 429; Proc. Geol. Soc. 1843, vol. iv. p. 164.

The above together with *Brentford*, Mag. Nat. Hist. N.S. 1838, vol. ii. p. 539.

Stutton (*Suffolk*), Loudon's Mag. Nat. Hist. 1834, vol. vii. p. 274.

† The distance between the east and west excavation is about 250 yards.

Fig. 1.—*Diagram showing the relations of the Freshwater Beds of the Copford Brickfield.*



1. Brown clay with pebbles, &c.
1′. Brown sandy loam.
2. Shell-marl and ferruginous sands (furrowed surface). Bones and shells.
2′. The same, passing into clay, rich with shells.
3. Vegetable bed. Shells.
4. Blue clay (brick-earth) } (not laminated). Bones and shells.
4′. Yellow clay, with "race." }
4″. Yellow and blue clays, laminated.
5. Grey sandy gravel. Shells and drifted fossils.
5′. Sandy gravel.

In digging through the bed No. 4 of the section (fig. 1), the workmen meet with a bed of sand and gravel (No. 5), with calcareous concretions, rounded chalk-debris, flints, both rounded and angular, boulders of lias, and other rock-fragments. This bed is very rich in fragments of *Ammonites, Ostreæ*, &c., and organic remains (for the most part small) derived from the tertiary and secondary formations.

Drifted Organic Remains from the Tertiary and Secondary Formations.

Lias.

Belemnites acutus.
Avicula inæquivalvis.
Nucula.
Pentacrinus Briareus.

Oolite.

Large fragment of bone, impregnated with iron pyrites.
Belemnites.
Rissoa.
Trochus.
Perna.
Ostreæ and Gryphææ (small).
Millericrinus? (*Goldfuss*, pl. 78. f. 7 *t* and 7 λ) and others (? Oolitic).
Echinodermata (spines).
Fish teeth.
Spirolina (Oxford Clay).
Chemnitzia ,,
Ammonites ornatus ,,
—— Lamberti ,,
—— Mariæ ,,
—— biplex (Kim. Clay).
—— spinosus ,,
Aptychus ,,
Exogyra virgula ,,
Pleurotomaria ,,
Serpula (Cornbrash).

Greensand.

Littorina carinata.
Serpula.

Gault.

Belemnites attenuatus.
—— minimus.
Inoceramus sulcatus.
Frondicularia.
Crustacean remains.
Fish teeth.

Chalk.

Plagiostoma spinosum.
Inoceramus (fragments).
Ostreæ (small).
Terebratulina striata.
—— gracilis.
Rhynconella Mantelliana.
—— Cuvieri.
Crania Egnabergensis.
Serpula granulata and others.
Apiocrinus ellipticus (ossicles).

Pentacrinus (ossicles), *Dixon, Foss. Sussex*, pl. 20. f. 6*a*, 7 *b*.
—, *ibid.* pl. 19. f. 15.
— Agassizii, *ibid.* pl. 19. f. 3*a*.
Cidaris sceptrifera and others.
Asterias and Ophiura.
Pollicipes maximus and others?
Bairdia subdeltoidea.
Cytherella ovata.
Frondicularia Verneuiliana.
— Archiaciana.
Flabellina.
Nodosaria Zippei.
Marginulina ensis.
Cristellaria rotulata.
Dentalina.
Spirolina irregularis.
— lagenalis.
Lituola nautiloidea.
Ventriculites.
Many species of Bryozoa.
Fish teeth (Lamna, &c.).

TERTIARY.

Potamomya. Bryozoa. Fish bones and teeth.

Land and Freshwater Shells from Bed No. 5.

Zonites rotundatus.
— crystallinus.
— nitidulus.
Carychium minimum.
Valvata piscinalis.
Bithinia tentaculata (chiefly opercula).
Odostomia?

The bed No. 4 consists of blue clay, containing a large quantity of calcareous matter. It is about 11 feet in thickness, and its surface is undulated throughout. At the southern part of the eastern excavation this bed passes upwards into a yellow clay (4^1, in the Section) 6 feet thick, with numerous small, irregularly rounded concretions of carbonate of lime ("race" of the workmen). In a section opened in the southern part of the field in 1836*, and separated from the eastern section by a strip of ground that is not worked, consisting probably of bed No. 5, and forming as it were a ridge traversing the field from E. to W., appears a yellow, sandy clay (4^2, in the Section), laminated, about 10 feet thick, dipping to the south, and there passing into, and alternating with, similar clay of a blue colour. In this laminated yellow clay are found numerous thin calcareous concretions, flat, and irregular in shape†; as well as a few of the roundish calcareous bodies, above mentioned. The yellow clay rests on a sandy gravel (5^1 in the Section); towards the surface it sometimes contains much chalk-debris; and at places it is seen to pass upwards into an obscurely laminated brown loam. In the west-

* See Loudon's Mag. Nat. Hist. vol. ix. p. 429.

† See Loudon's Mag. Nat. Hist. 1836, vol. ix. p. 430. The following observations on the "Race," both from the laminated and the non-laminated clays, have been kindly supplied by H. C. Sorby, Esq., F.G.S. When a portion of the soft part of one of the subglobose bodies above referred to is spread in water and examined under a high power with polarized light, it is seen to consist of fine grains of quartz-sand, mica, more or less decomposed felspar, peroxide of iron, and a large proportion of calcareous particles. The greater part, if not the whole, of the calcareous particles appear to have been derived from chalk; for numerous characteristic fragments of the *Foraminifera*, of which that deposit is almost entirely composed, are found in it. The harder portions, and a considerable proportion of the soft, present such characters as render it almost certain that they had a similar origin, but that they have since undergone a considerable amount of crystalline consolidation; and this is especially the case with the hard, flat pieces, which have a waterworn appearance, whose structure is identical with the harder parts of the rounder and softer ones. On the whole, I am of opinion that they were formed from a mixture of chalk and fine clay, and that they have since been consolidated by the action of carbonic water; and this process, having in some cases proceeded from certain centres, has given rise to the nodular portions.

ern part of this excavation (which is somewhat basin-shaped), the yellow clay laminæ vary in their dip from S. to S.E. and to nearly E. This laminated yellow and blue clay is, in my opinion, the same as the blue clay of the eastern and western sections, which latter is co-extensive with the other beds, hereafter mentioned, that occupy the site of what appears to have been an ancient freshwater lake, being more than a mile in extent from east to west, and about three-quarters of a mile in a north and south direction.

The clay undergoes a process of puddling and washing in a horse-mill preparatory to its being used in brick-making; and from the debris of these washings various organic remains and rock-fragments have been obtained:—rolled fragments of chalk, rolled and angular flints, fragments of Kimmeridge clay, and minute fossils from the upper secondary rocks.

I have formerly noticed the occurrence of fragments of freshwater shells in the upper part of the blue clay (No. 4 of the Section), especially *Valvata* and opercula of *Bithinia*; and on a recent re-

Fig. 2.—*Metacarpal of large Bear, from Copford.*

a. Upper surface.
b. Proximal articular surface.
c. Lateral view.

Fig. 3.—*Molar Tooth of Extinct Beaver, from Copford.*

a. Lateral view.
b. Grinding surface.

examination of portions of this bed, the following remains have been found :—

Limneus pereger.	Valvata cristata.
Succinea.	Cyclas ?
Planorbis albus.	Pisidium amnicum.
—— imbricatus.	Candona reptans.
Bithinia (opercula).	—— lucens.
Valvata piscinalis.	Cypris gibba.

The shells are much more abundant in the upper part of the clay than below, which latter is mixed with siliceous sand, ferruginous grains, minute fragments of chalk, and a few of the most common chalk *Foraminifera*, together with portions of *Sphagnum*.

The following also have been obtained from the blue clay :—

Elephant ; cuneiform bone of right fore-foot, large fragments of leg bone, and fragments of ribs.
Stag ; scapula and antlers.
Aurochs ; horn-core.
Bear ; metacarpal bone (fourth digit). Very large species (fig. 2).
Beaver ; two molar teeth*. Extinct ? species (fig. 3).

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* Some observations by Mr. Waterhouse on the Beaver teeth and the Bear's bone are given in the following note :—

"British Museum, July 16, 1852.

"My Dear Sir,—I have compared the two molar teeth of the Beaver, from Copford, with the teeth of the European and North American species, also with the teeth of a Beaver from the Fens of England, and with those of a jaw found at Ilford. I have little doubt that the Copford tooth, above figured, is the second molar of the right side of the lower jaw. It may be observed that this specimen differs from all, in the direction of the folds of enamel, and in being larger.

"The hindermost of the three inner folds of enamel runs directly inwards, and meets the outer fold in the middle of the tooth ; and both folds are perfectly straight. In the European Beaver, the inner fold in question, upon meeting the outer fold, is bent suddenly backwards ; besides which, in the recent skull and in the fossil from Ilford, there is a second little branch thrown backwards from the posterior internal fold.

"The transverse diameter of this tooth measures 5 lines[1] at the crown, and 6 lines at the root ; and the antero-posterior diameter of the crown is 4 lines[2] ; from this it will be seen that the crown of the tooth as represented in the woodcut is rather under the natural size. The second Beaver tooth from Copford scarcely differs from that of the European species.

"The foot-bone belongs to a Bear of large size (fully equal to the *Ursus spelæus* in this respect), and is the fourth metacarpal of the right fore-foot.

"Faithfully yours,

"*To John Brown, Esq., F.G.S.*" "Geo. R. Waterhouse."

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[1] Scarcely 4 lines in a very large Beaver skull (rather more than 6 inches in length) from the River Donau.

[2] Four lines in the Beaver skull from the River Donau. The proportions, then, of the crown of the Copford tooth differ from those of the recent animal. The enamel of the Copford tooth is broken away at the extreme edge in the front of the tooth, but this is allowed for in the dimension.

On this calcareous clay we have a very compact deposit of vegetable matter (No. 3 of the section), generally from 3 to 12 inches thick, but at the eastern section it increases northward to a thickness of 6 or 7 feet. It is similar to peat, but not so inflammable, having a small portion of argillaceous matter distributed throughout its mass. It is often incorporated with the upper portion of the blue clay. In this bed have been found compressed branches of trees and shells of the *Valvata piscinalis*, and in 1836 I found *Cyclas rivicola* in groups.

Over this layer of vegetable matter there occurs a bed of shell-marl (No. 2 of the section), from 1 to 6 feet thick, which lies conformably on the undulatory surface of the blue clay, into which it sometimes sends down oblique veins (west section). This bed dips to the north with a slight angle (about 5°), and thins out towards the southern part of the brick-field. It varies considerably in its character throughout this area, sometimes consisting wholly of a white calcareous marl, having a chalky appearance, and sometimes of the latter alternating with ferruginous sands, or passing into sand or clay. In the western excavation it is chiefly composed of white sand and shell-fragments (*Valvata piscinalis*). In the first-named condition, no shells or parts of shells have been found in it, although most probably it is wholly derived from the decomposition of accumulated remains of dead molluscs. When it becomes sandy, however, both broken and perfect shells are not rare; but when it passes into clay, the remains of land and freshwater molluscs are abundantly found in a perfect state. In the light-coloured clay (2^1, of the Section), into which the marl passes in one part of the eastern section exposed in 1850, thirty-two species have been found.

List of Land and Freshwater Molluscs from the Copford Shell-marl (2 and 2^1 of the Section).*

Land Shells.

Limax agrestis (W.).†
—— carinatus (E.).
Helix hortensis (W.E.).
—— nemoralis (W.E.).
—— arbustorum (W.E.).
—— hispida (W.E.).
—— concinna (W.E.).
—— pulchella (W.E.).
—— fulva (W.E.).
—— fusca (E.).
—— rufescens (W.E.).
—— depilata (E.).
—— aculeata (W.E.).
—— lamellata (W.E.).
—— incarnata? (W.) (Extinct.)
—— sericea (W.).
—— lapicida (W.).
Helix ruderata (W.). (Extinct.)
——, ova of (W.).
Zonites rotundatus (W.E.).
—— radiatulus (W.E.).
—— purus (W.).
—— nitidulus (W.E.).
—— pygmæus (W.E.).
—— crystallinus (W.E.).
—— cellarius (W.).
—— alliarius (W.).
—— lucidus (W.).
Bulimus obscurus (W.).
—— acutus? (W.).
Azeca tridens (W.).
Zua lubrica (W.E.).
Pupa marginata (W.).
—— umbilicata (W.).

* The nomenclature here used is that of Gray's 'Turton's Manual,' in accordance with which the shells were named when the collection was first formed.

† W. denotes that the shell has been found in the western part of the field, and E. in the eastern part.

Pupa anglica (W.).
Vertigo palustris (W.E.).
—— pusilla (W.E.).
—— edentula (W.E.).
—— pygmæa (W.).
—— angustior (W.).
—— alpestris (W.).
Vertigo substriata (W.).
Clausilia bidens (W.).
—— nigricans (W.).
—— Rolphii (W.).
Achatina acicula? (W.).
Carychium minimum (W.E.).
Acme fusca, and var., reversed (W.).

Freshwater Shells.

Succinea putris (W.E.).
—— Pfeifferi (W.E.).
Limneus truncatulus (W.E.).
—— pereger (W.).
—— palustris (W.E.).
—— stagnalis? (W.).
Physa hypnorum (W.).
Planorbis spirorbis (W.E.).
—— contortus (W.).
—— marginatus (W.).
—— imbricatus (W.).
Planorbis nitidus (W.).
—— albus (W.).
—— vortex (W.).
Bithinia tentaculata (W.E.).
—— ventricosa (W.).
Valvata piscinalis (W.E.).
—— cristata (E.).
Pisidium obtusale (E.).
—— pulchellum (E.).
—— pusillum (W.).
Unio or Anodon, fragments of, ? (W.).

Entomostraca.

Valves of Candona lucens (W.).

In this marl the horn-core and bones of Ox, antlers of Stag, and bones of Elephant have been met with.

It may be observed that the shell-marl does not appear to be of much use to the agriculturist as a top-dressing, it having failed to produce the effects which result from the application of chalk to the land.

Figures of the two extinct land-shells above-mentioned are given in the accompanying woodcut, fig. 4.

Fig. 4.—*Extinct Shells from the Freshwater Beds at Copford.*

a—c. Helix incarnata. d, e. Helix ruderata (magnified).

Overlying the white marl is an unstratified deposit of reddish-brown clay (No. 1 of the section), containing chalk-nodules, rounded and angular flints, boulders of greywether and other sandstones, limestones, conglomerates, and porphyritic rocks. This clay is from 1 to 6 feet thick; the greatest thickness occurring in the northern part of the field. To the south it passes over the limit of the marl-beds, and rests on the yellow bed into which the blue clay or brick-earth passes. No organic remains have been found in this brown clay, excepting a molar tooth of a Horse, and this was obtained near its junction with the white marl.

At the western and northern parts of the field there is a superficial bed of peat, about 1 foot in thickness, with recent land and freshwater shells, many of which retain their epidermis.

Having thus described the Copford deposits in detail, I would observe that the sandy gravel, No. 5, appears to me to belong to the Till or Boulder-clay. The blue-clay or brick-earth (No. 4) I have long considered to be a modification of that deposit on account of its organic and mineral contents, which have originally been derived from a distance; and the brown clay with boulders also (No. 1) certainly contains evidence of an origin identical with that of the boulder-clay. The angular flints and sandstone-boulders especially, scattered over the surface here, are similar to those of the Till of the neighbouring parts of Essex. From the Till of Bures, and in the cutting of the Stour Valley Railway, fossil remains have been obtained in great abundance, together with boulders and angular fragments derived from various of the older formations. The Till continues southward from Copford to near the coast, at places assuming a more chalky character.

List of Rocks and Minerals forming Boulders and Gravel in the Till of Copford and its neighbourhood.*

London Clay Septaria. Copford.
Nodules of Pyrites and Crystals of Selenite.
Greywether Sandstone (one angular block weighing 30 cwt.).
Hertfordshire Puddingstone, in large angular fragments.
Chalk, in large boulders.
Unrolled chalk-flint and large angular flints. Copford.
Limestones, with and without fossils (Oolite, Lias, &c.). Copford.
Hard Lias Limestone, grooved and polished.
Porous siliceous rock†; abundant in the Till and gravels of the neighbourhood.

* For a list of Rock-specimens from the Till of Ballingdon Hill, Essex, see Mag. Nat. Hist. 1836, vol. ix. p. 43.

† Mr. Sorby has obligingly favoured us with some remarks on this peculiar rock. This rock, he observes, is one of great interest, having such a structure as to well deserve a detailed description, which I shall probably give on some other occasion. At present I need only say that it appears to have been, originally, similar to one of those varieties of limestone which consist to a great extent of fine rounded grains of calcareous organisms, more or less slightly coated with a layer of the same in a more finely comminuted condition, along with a little fine clay, so as to form an incipient oolite, the grains of which have not received so thick a coating as to develope a genuine oolitic structure. I am not acquainted with any of *exactly* the same character as this appears to have had, but some of the oolites in Lincolnshire are very closely allied to it. Its present condition has resulted from silicification, which has removed the calcareous matter, and left the spaces, originally occupied by the round oolitic grains, either empty or filled with agate. The sides of those which are empty are covered over with radiate crystals of agate; and the surrounding mass is transformed into a somewhat similar structure. The rudimentary oolitic grains were on an average about $\frac{1}{170}$th of an inch in diameter, and about one-half are now empty, which gives the rock so porous a character. It also contains fragments of agatized shell with the structure very perfectly preserved.

Mr. S. has also examined two other forms of concretionary structure in rock-fragments from bed No. 5 of the Copford section, one of which is silicified, and, in Mr. Sorby's opinion, a pseudomorph; and the other presents the form of oolitic structure termed by Mr. S. "positive concretionary." He considers it probable that both have been originally formed from chalk-debris.

Chert, in large angular blocks.
Mountain Limestone (one angular block weighing 2 tons).
Black Marble, in large boulders.
Coarse Sandstone and fine-grained micaceous Sandstone. Copford.
Black Slate, in angular fragments.
Quartz-rock and grauwacke. Copford.
Coarse-grained Quartz-rock, with mica.
Basalt. Copford.
Felspar-porphyry, large angular masses.
Syenite, large rounded masses.

List of Fossils from the Till of the Eastern Counties.*

Elephas; tibia, right and left ischia, symphysis of lower jaw, molar teeth of lower jaw (young and adult).
Equus; phalangeal bone.
Vertebræ of Saurians (Stour Valley).
Ammonites serratus (Stanway, Stour Valley, Hartest).
—— rotundatus (Hartest).
—— biplex (Suffolk).
—— dentatus
—— Lamberti
—— Leachii?
—— Bakeriæ
—— Gowerianus?
—— annularis
} (Stour Valley.)

Gryphæa incurva; Lias
Pecten; Lias
Spatangus; Chalk
} (Stour Valley.)

It is a peculiar feature of the Till in this county, that it contains interrupted beds and small masses of gravel, consisting of rounded and angular flints, sandstone, and other rock-fragments, imbedded in *greyish* sand; which colour is peculiar to this gravel. We find such a gravel underlying the Till at Kelvedon, Thaxted, and Ballingdon (in the latter place the beds are highly inclined,—false-bedded), and at Muswell Hill near London; and, in my opinion, the gravelly sand underlying the blue calcareous clay of the Copford Brick-field, above-described, may be referable to this *grey* gravel. The masses of this gravel are so limited, that five pits have been exhausted in the course of twenty years, in obtaining materials for mending the roads, in the parish of Copford alone.

The *red* gravel in the adjoining parish of Stanway forms an enormous mass, several miles in length towards the east, more than a mile in width, and in some places 60 feet in thickness; and being *red*, is different in colour to the gravel in the Till. Not knowing whether the interrupted beds of *grey* gravel in the Till extend to

* See also Woodward's 'Geology of Norfolk,' pp. 39 *et seq.*, and some of the figures of fossils in R. C. Taylor's 'Geology of East Norfolk.'

other parts of England, I have thought their occurrence in this district worthy of remark, and as being likely to elicit the attention of other observers of our tertiary beds.

In conclusion, I have to draw attention to the discovery of two extinct molluscs (*Helix ruderata* and *H. incarnata*?, see fig. 4) in the Copford marls,—a fact of considerable importance in estimating the relative age of this deposit; and I would observe, that not the least interesting phænomenon of the Copford freshwater beds is the superposition of an upper member of the local boulder-formation (bed No. 1) on the shell-marl, which latter, with its subjacent clays, rests on an earlier member of this formation,—conditions clearly pointing out the age of the intercalated deposit. This seems to accord also with an analogous geological phænomenon in the cliffs of Eastern Norfolk and in other localities, as noticed in Sir C. Lyell's 'Manual of Elementary Geology,' p. 127.

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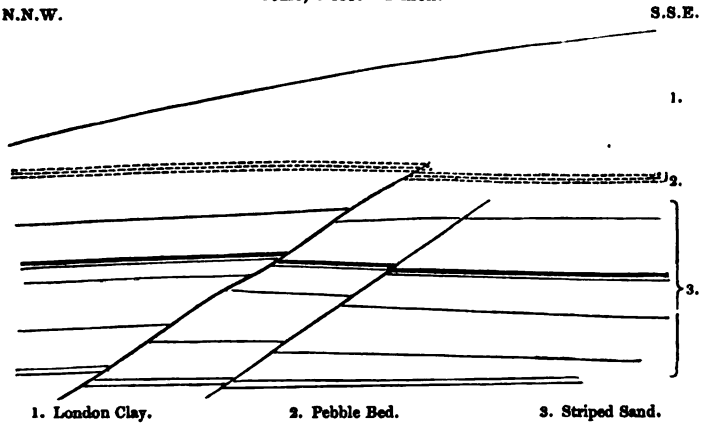
2. *On a* Reversed Fault *at* Lewisham.

By the Rev. H. M. De la Condamine, A.M., F.G.S.

A recent section on the northern slope of Loam-pit Hill exhibits distinctly a small "reversed" fault in the lower tertiary strata; and the comparative rarity of this phænomenon appears to render it desirable that its existence in this locality should be noticed*.

Fig. 1.—*Section at Loam Pit Hill, showing the Reversed Fault.*

Scale, 6 feet = 1 inch.



The accompanying section (fig. 1) will show its precise character. The average angle of fracture is 30°: the displacement 6 inches. Its

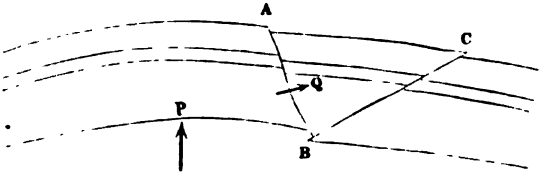
* See an instance recorded by Messrs. Prestwich and Morris, Quart. Journ. Geol. Soc. vol. ii. p. 402.

direction, as exposed for 50 or 60 yards, is E.N.E., being nearly parallel to the dislocations at Deptford and Greenwich*. It is attended by a slight anticlinal line of flexure, indicative of the lateral pressure which was likely to give rise to fractures of this peculiar character, and the effects of which are seen in the contorted strata at New Cross†.

The second line of fracture, which dies away both upwards and downwards, would indicate that the strata sustained a wrench, to which they yielded without suffering complete fracture; and possibly the main fissure may not be continued to any great depth.

The subjoined diagram (fig. 2) illustrates the action of the force which may have produced this dislocation.

Fig. 2.—*Diagram to illustrate the Mode of Formation of the Reversed Fault at Lewisham.*



Supposing P to be a centre of maximum vertical pressure, producing a fault AB, a lateral pressure Q would result, causing a wrench or fracture along a line BC. The same result would follow, if the pressure at P caused only an anticlinal elevation without fracture at AB.

This theoretical diagram very nearly resembles the actual phænomena of a section taken at right angles to the line of dislocation (see section, fig. 3).

The great obliquity of this fault, viz. 30°, has induced me to investigate a formula for the apparent deviation of a line of fault (as laid down on a map) produced by the undulations of the surface.

If α, β be the inclinations of a fault and of the surface respectively, and γ the angle between the direction of the fault and a horizontal line on the surface, then the angle of deviation ϕ is given by the formula

$$\tan \phi = \frac{\sin \gamma}{\tan \alpha \,.\, \cot \beta - \cos \gamma}.$$

Hence also the inclination of a fault may be determined by observation of the other angles.

This formula may equally well be applied to mapping the outcrop of strata whose dip is known.

Applying this to the subject of this notice, the fall of the ground

* Quart. Journ. Geol. Soc. vol. vi. p. 447, fig. 5.
† *Loc. cit.* p. 448, fig. 6.

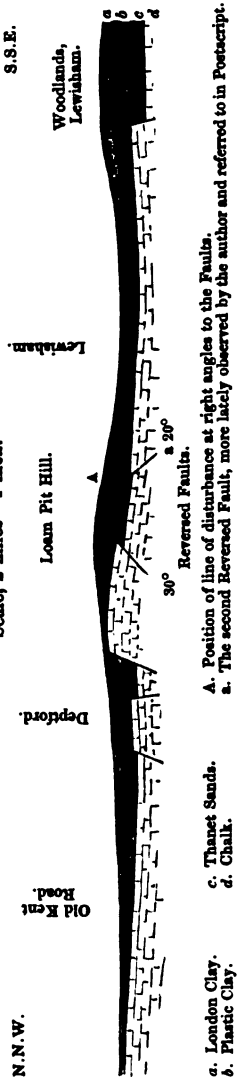


Fig. 3.—*Section showing the position of the Faults at Loam Pit Hill.*

being towards the E.N.E. at an angle of 5°, we find $\phi = 9°$. This would bring the line of fault through the middle of a tolerably long cutting 150 yards off. No trace of it, however, appears there; whence it probably is not of considerable extent either horizontally or vertically.

About 200 yards from this fault, and at right angles to its direction, a line of disturbance runs N.N.W. and S.S.E. (fig. 3, A). It is marked by a sudden increase of dip, from 3° to 11°, and by a series of small faults, greater in amount than the above-mentioned, but producing no displacement exceeding 2 feet. It illustrates, however, the well-known law of elevation, and is repeated on a much larger scale at Hornpark, near Mottingham, where the E. and W. faults of Lee, Eltham, and Woolwich are intersected by a great fault running N. and S.

P.S. Another small reversed fault has been exposed since the above paper was read. This also runs E.N.E., with an angle of fracture of only 20°, but having the upcast on the north side, instead of on the south. A line representing its position has been introduced into fig. 3, a little to the north of A. It supplies further evidence of the lateral pressure above alluded to. [April 16, 1852.]

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3. *Notes on* St. Helena. By J. H. Blofeld, Esq., F.G.S.

[Abstract.]

In this paper the author briefly noticed the general external characters of the island and some of its geognostical phænomena, and more especially described the conditions under which the fossil shells of

Bulimi, Succineæ, and *Helices** are found in the superficial soils of the island†. The *Bulimus auris-vulpina* is not now found in a living state. The shells are met with in various elevated parts of the island. The specimens accompanying this communication were found by the author about half a mile behind Longwood, at an elevation of about 1700 feet above the level of the sea, on a hill-side which is worn into numerous clefts or ravines by the heavy rains. The surface of the hill to a depth of 5 to 6 feet consists of dark mould, and under this is a stratum of a greyish-brown friable earth about 3 to 4 feet thick; in this latter bed the shells occur‡. This earth also contains bird-bones§, perfect and fragmentary, in abundance; and it was suggested by the author, that possibly in some cases the shells may have been brought to the spot by birds that fed on their living occupants.

The *B. auris-vulpina* is accompanied by *B. subplicata* and *Helix bilamellata*. In the "shell-bed" are found numerous lumps of several sizes, composed of a white powdery substance, and associated with a harder yellow substance‖. Some specimens of a new species of *Bulimus* (*B. Blofeldi*, E. Forbes), collected by the author, also accompanied this paper. These were found (together with some young *Helix bilamellata*) in a reddish clay or loam on the side of a hill overlooking the "Briars" in the cutting of the road from James Town to Longwood, about 1200 feet above the sea-level, and about two miles in a direct line from the spot where the larger *Bulimi* were found.

* Detailed descriptions and figures of these shells are given by Prof. E. Forbes in the next following communication.

† For a detailed description of the Geology of St. Helena, see Darwin's 'Volcanic Islands,' pp. 73 *et seq.*

‡ This deposit is composed chiefly of vegetable matter and carbonate of lime. The latter is present, both in the form of prismatic crystals (shell-tissue?), and as the coating of vegetable fibres. The majority of the specimens of *B. auris-vulpina* presented to the Geological Society's Museum by the late Mr. Seale, F.G.S., were imbedded in a whitish coherent sand, consisting of grains (chiefly inorganic) coated with calcareous matter.

§ Prof. Owen, having examined these bones, pronounces them to belong to marine birds. The Professor has also examined some specimens of similar bones from Turk's Cap Bay, St. Helena, presented to the Geological Society by Captain Wilkes, R.N.; these also are all bones of marine birds, most of them being of the Petrel kind; some of them belong to the subgenus *Puffinus*. The bones from Turk's Cap Bay are from a greyish-brown earthy deposit, containing much inorganic sand, the grains of which are partially coated with calcareous matter.

‖ This white substance has been chemically examined by Dr. Percy, F.G.S., who observes, that it consists of matter soluble in nitric acid with effervescence, with the exception of a small quantity of insoluble residue, probably siliceous. The soluble matter is carbonate of lime, sulphate of lime, carbonate of magnesia, and phosphoric acid in combination with sesquioxide of iron. The harder yellow portion was found to contain organic matter, possibly the cause of the yellow colour, and to be similar in constitution with the white powder.

This substance may possibly be the same as that referred to by Mr. Darwin in the footnote at page 87, 'Volcanic Islands.' Under the microscope much prismatic matter is visible, which might readily be taken for the carbonate of lime liberated from the prismatic cells of shell-tissue; but, as this withstands to some extent the action of nitric acid, it would appear to be sulphate of lime.

4. *On the* Extinct Land-Shells *of* St. Helena. By Prof. Edward Forbes, F.R.S., G.S.

[Plate V.]

The presence in St. Helena of considerable numbers of a remarkable extinct univalve once supposed to be of marine origin, and described by mistake as from China, but afterwards proved to be a land-snail of the genus *Bulimus*, has long been known. This shell, to which the name of *Bulimus auris-vulpina* (Férussac) has been given, is of considerable dimensions, and hence had attracted the notice of collectors. Their true position was first indicated by Mr. Seale, a resident of the island, who communicated other species found with this and elsewhere in the island to Mr. Darwin. These are described by Mr. G. B. Sowerby in the appendix to Mr. Darwin's work upon Volcanic Islands. There are other forms of land-mollusks, not now known as living species, associated with it.

The slight knowledge which we possess at present respecting the details of the natural history of St. Helena prevents our asserting with confidence that these forms are extinct. A small collection of existing shells brought from this locality by my friend and pupil Mr. Edward Alexander affords some additional means of comparison. The same gentleman procured some subfossil forms hitherto unobserved, and one or two others have been brought home by Mr. Blofeld.

I take this opportunity of placing these on record, with a remark on the indications they afford of the ancient geographical relations of the island in which they occur.

The so-called "subfossil" St. Helena shells with which I am acquainted are five species of *Bulimus*, one of *Achatina*, one or two of *Helix*, and one of *Succinea*. The existing indigenous land-shells of St. Helena are five species of *Bulimus*, two *Achatinæ*, three *Helices*, and two species of *Succinea*.

Of the five subfossil *Bulimi*, the affinities of two are decidedly and remarkably South American. The *Bulimus auris-vulpina* is unlike any Old World form, and its relations must be sought for in the Brazilian *B. bilabiatus*, and probably *B. melanostoma* and its allies. For allies of the equally peculiar *Bulimus Darvinianus* we must also go to Brazil and compare with *B. goniostoma* and similar types. Of the other two, the affinities are with species now living in St. Helena. *Bulimus Sealeianus* is nearly allied to *Bulimus Helena* of Reeve (not of Quoy) and the *Achatina exulata* of Benson. *Cochligena fossilis* of Sowerby is allied to this, but very distinct. *Bulimus Blofeldi* is nearly allied to an existing undescribed species found by Mr. Alexander feeding on the cabbage-trees only on the highest points of the island. The affinities of the latter are decidedly West-African; those of the former point in two directions, African and South American, the latter character possibly prevailing.

An *Achatina*, called *Cochlicopa subplicata* by Mr. Sowerby, is chiefly connected with West Indian forms, but has also relations on the west coast of Africa, such as the *A. clavata* of Sierra Leone.

Mr. Sowerby described an allied species under the name of *Cochlicopa terebellum*.

The subfossil *Succinea* is of a very ordinary character, as is the case with the majority of species of this genus all the world over, though, curiously enough, one of the living St. Helena *Succineæ* is remarkable for its peculiarities.

One of the *Helices* is most nearly related to Madeiran types. Mr. Sowerby has described four species, *H. bilamellata*, *H. polyodon*, *H. spurca*, and *H. biplicata*, in his note on Mr. Darwin's collection. I have examined the first and third of these.

I have endeavoured elsewhere* to show that all the information we possess respecting the marine mollusks of the coasts of St. Helena would lead us to infer the very ancient isolation of that island, whilst at the same time a pre-existing closer geographical relationship between the African and American continents than now maintains is dimly indicated. The information we have obtained respecting the extinct and existing terrestrial mollusks of this isolated fragment of land would seem to point in the same direction, and assuredly to indicate a closer geographical alliance between St. Helena and the west coasts of South America than now holds.

Descriptions of the New Species.

Bulimus Darvinianus. Plate V. fig. 1.

Testa crassa, elongato-oblonga, fusiformis, subumbilicata; anfractus 5, convexiusculi, ad suturam crispati; sutura impressa; apertura oblonga, basi canaliculata angulataque; columella contorta; faux supra columellaris plicata; peristoma continuum; labrum intus incrassatum. Long. 1½ unc., lat. 0⅔ unc.

Found by Edward Alexander, Esq.

Bulimus Sealeianus. Plate V. fig. 3.

Testa oblongo-pyramidata, crassa; anfractus sex, convexiusculi, oblique striati, ultimus maximus; apertura oblongo-lenticularis, infra angulata; peristoma continuum, incrassatum. Long. 0$\frac{7}{10}$ unc., lat. 0$\frac{4}{10}$ unc.

Found by Edward Alexander, Esq.

Bulimus Blofeldi. Plate V. fig. 2.

Testa tenuis, pyramidalis, ventricosa, lævis, umbilicata; anfractus 5, tumidi, ultimus maximus, ovatus; apertura ovata, infra angulata; labrum columellare rectum; peristoma disjunctum; margo tenuis. Long. 1$\frac{1}{10}$ unc., lat. 0½ unc.

Found by J. H. Blofeld, Esq., F.G.S.

Succinea Bensoniana. Plate V. fig. 7.

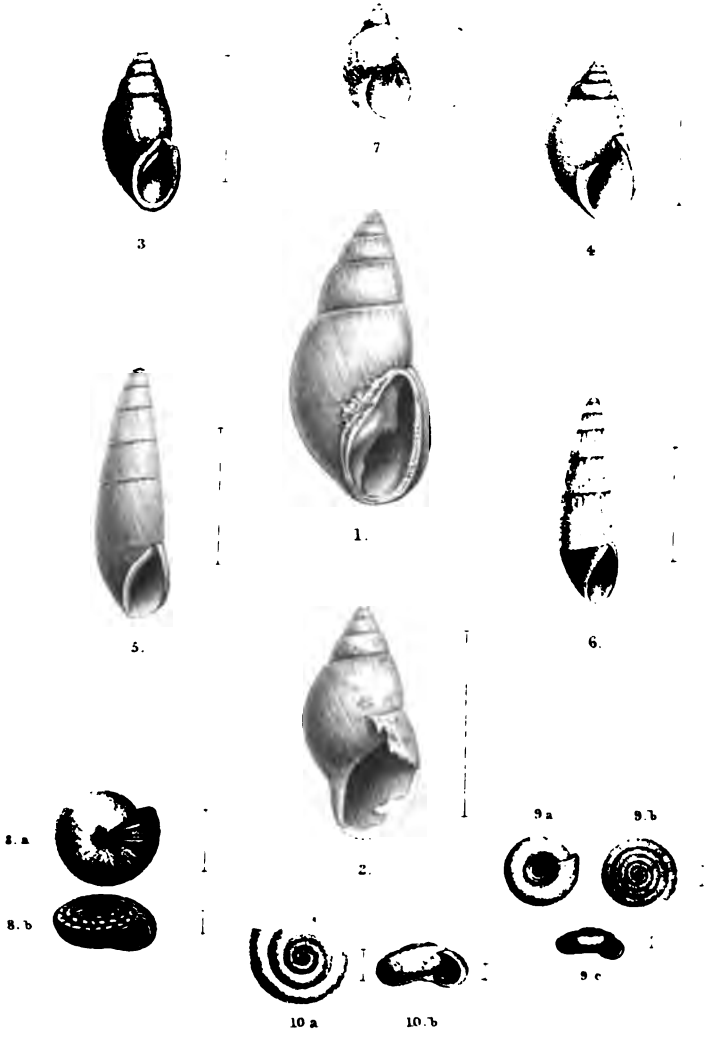
Testa ovata; spira brevis; anfractus 3½, ultimus maximus, ventricosus; apertura ovato-rotundata. Long. 0$\frac{4}{10}$ unc., lat. 0$\frac{3}{10}$ unc.

Found by Edward Alexander, Esq.

Helix Alexandri. Plate V. fig. 9.

Testa orbicularis, depressa, convexiuscula; anfractus septem, rotundati, forte

* Rep. Brit. Assoc. for 1851.



F Reeve imp

St HELENA FOSSILS.

1 Bulimus Darwinianus
2 ... Bowdeni
3 ... Sowerbianus
4 ... [illegible]
5 ... terebellum
6 Bulimus strigatus
7 Succinea Benseniana
8 Helix bilamellata
9 ... Alexandri
10 ... spurca

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TILDEN FOUNDATIONS
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striati; apertura semilunaris, labio interno plicis tribus spiralibus, externo intus octo instructo; umbilicus maximus. Long. $0\frac{1}{12}$ unc., lat. $0\frac{8}{12}$ unc.

Found by Edward Alexander, Esq.

The following species also, hitherto unfigured, are represented in Plate V.:—

HELIX BILAMELLATA, Sowerby. Plate V. fig. 8. From a specimen found by Mr. Blofeld.

HELIX SPURCA, Sowerby. Plate V. fig. 10. From a specimen found by Mr. Alexander.

BULIMUS FOSSILIS, Sowerby. Plate V. fig. 4. From a specimen in the Museum of the Geological Society.

BULIMUS TEREBELLUM, Sowerby. Plate V. fig. 5. From Mr. Darwin's examples in the cabinet of Sir Charles Lyell.

BULIMUS SUBPLICATUS, Sowerby. Plate V. fig. 6. From a specimen found by Mr. Blofeld.

MARCH 24, 1852.

The following communications were read:—

1. *On the* FOOT-PRINTS *occurring in the* POTSDAM SANDSTONE *of* CANADA. By W. E. LOGAN, Esq. F.G.S.

[PLATES VI. to VIII.]

SINCE the reading of the paper communicated to the Society last year on the track and footsteps of an animal in the Potsdam Sandstone of Lower (East) Canada*, the lowest member of the Lower Silurian rocks, farther investigation by my assistants on the Provincial Survey and myself have brought to light a considerable number of similar tracks in the same rock; and, although quite convinced in my own mind of the age of the rock, the importance attached to these impressions has induced me to search for additional evidence on the point, in order that others as well as myself might be satisfied that no mistake had been made in regard to it.

In my previous paper it was stated that a sandstone formation, resting unconformably on a metamorphic series of gneiss and interstratified limestone, and occupying a narrow strip at a variable distance on the north side of the St. Lawrence, swept round from the valley of this river to that of the Ottawa, the turn forming an obtuse angle and occurring on the Rivière du Nord: that a similar rock, proceeding from Keesville in New York, turns from the Valley of Lake Champlain to that of the River St. Lawrence, and, forming at the bend a sharper angle, is projected out across Beauharnois towards the previously mentioned bend in a long tongue of sandstone, pierced near the extremity by Mont Calvaire, a protruding mass of

* Quart. Journ. Geol. Soc. vol. vii. p. 247 *et seq.*

the subjacent gneiss. From Beauharnois the rock has been traced in New York in a nearly straight south-west line, and at a distance of five to thirty miles from the south-east bank of the St. Lawrence, to Hammond and Alexandria on that river. Crossing the river then to Brockville, it was last summer followed in Canada through the Johnstown and Bathurst Districts in a tortuous course to the townships of M'Nab and Nepean on the Ottawa; and on this river it has been seen again once, below Bytown, trending to a junction with the exposure on the Rivière du Nord. Between Mont Calvaire and the Bathurst District it may thus be considered to form the perimeter of a peninsula-shaped area, the isthmus to which, between the exposures at Mont Calvaire and Rivière du Nord, is about ten miles wide. Around the whole of this peninsular space the sandstone rests upon the gneissoid metamorphic rocks, and it is succeeded by an interior zone of calcareo-arenaceous beds, bearing the fossils which characterize the Calciferous Sand-rock series of New York. Within this is another zone consisting of limestone corresponding in a considerable degree in its fossil contents with the Chazy Limestone; the organic remains of a large area in the centre can be identified with those of the Bird's-eye, Black River, and Trenton Limestones, and resting on the latter a trough of the Utica Slate with its characteristic *Trilobites* and *Graptolites* extends from Bytown some distance eastward. This concentric geographical arrangement of the rocks, even without the evidence of the dips, leaves little doubt that the more organic formations rest on the sandstone. Where the dips are appreciable, they give a general confirmation of this; but they are for the most part small, and strata over large areas have often to the eye the appearance of being quite flat. The east side of the Beauharnois tongue of sandstone is bounded by the same succession of formations.

The sandstone in Beauharnois County and the neighbouring part of the State of New York is from 300 to 700 feet thick. In the lower part it contains many beds of conglomerate with quartz-pebbles, and it has some red layers; but towards the top it becomes a fine-grained, hard, white sandstone, and at the summit it is interstratified with calcareous layers forming a passage to the rock which overlies it. In this part it is abundantly marked over considerable surfaces by what the geologists of New York have called *Scolithus linearis*, which consists, where the rock is weathered, of straight, vertical, cylindrical holes, of about an eighth of an inch in diameter, descending several inches, and, where the rock is unweathered, of corresponding solid cylinders, composed apparently of grains of sand, cemented by a slightly calcareous matrix, more or less tinged with peroxide of iron. Mr. Hall and other American geologists include them among the Fucoids of the rock, but they appear to me more like Worm-holes. In one or two instances I have perceived that the tubes are interrupted in their upward course by a thin layer of sand, of a portion which descends into them and stops them up; and from this it would appear that the cylinders were hollow when the superincumbent sand was spread over them. Whatever may be the origin of the tubes, they strongly mark many beds in the upper part of the

sandstone throughout the Canadian portions of its distribution already mentioned; and it is stated by Mr. Hall that the same characteristic accompanies the Potsdam sandstone in New York and Pennsylvania, and as far as Tennessee.

With this part of the formation also are associated many indications of what have been considered as Fucoids. One form among others presents a reticulated arrangement of stem-like bodies spreading over some of the surfaces, the interspaces of the network being four-, five-, and six-sided, and sometimes, when largest, measuring 14 inches in diameter; while the ridges which divide them are an inch and a half wide, and stand out half an inch in relief on the sandstone. The compartments are sometimes filled with shale, and the low ridges, a good deal resembling crack-casts, might be taken for such, were not similar forms occasionally traceable on splitting open closely joined surfaces of sandstone where no shale intervenes, and were not smooth surfaces of arenaceo-bituminous limestone in the succeeding formation met with presenting black bituminous pellicles arranged in similar reticulated figures—both large and small.

At Beauharnois, in the locality in which the first Track was discovered, and on a bed in the same quarry, the trail of a Worm or of a Mollusk was very beautifully displayed; and in the Johnstown District not only do *Scolithus* and Fucoids exist in abundance, but my associate, Mr. Murray, has there met with *Lingula antiqua*, characterizing this part of the formation, as it does also at Hammond on the south side of the river.

The new localities in which foot-prints have been met with are five in number. In none of them is *Lingula* found immediately near, but *Scolithus* abounds in them all, as well as the Fucoids. Two of the new localities are in the vicinity of Beauharnois (see Map, Pl. VI.); one of these, in the field of Mr. Henault, is about half-a-mile westward of that in which the first impressions were discovered; the other about two-and-a-half miles still further westward, and about 500 yards from the mouth of the Beauharnois Canal. *Scolithus* and Fucoids are seen in beds a few feet above and a few feet below those having the foot-prints, and 7 feet below one of them the Worm-holes are accompanied by a thin band of interstratified limestone. Along the shore of Lake St. Louis, between the two localities, the sandstone, with the occasional appearance of a calcareous layer, can be seen nearly the whole distance, and a careful admeasurement of the distance and of the minute changes that occur in the very moderate dips prevailing enables me to bring the track-bearing beds to within 3 feet of one another in stratigraphical place, while geographically their positions are equivalent in relation to the Calciferous Sand-rock which on each side bounds the more siliceous formation.

Proceeding eastward from the exposures in Henault's field and the tracks on the St. Louis River (those first discovered), the sandstone, marked by *Scolithus*, can be followed along-shore for about a mile, and is very nearly flat. Then there is an interval of about a mile without any exposure, beyond which the Calciferous Sand-rock first makes its appearance. Thin interstratified bands, more arenaceous

than others, are still characterized by *Scolithus*, and the more massive beds hold abundance of two species of *Maclurea*,—*M. matutina* of Hall, and a new species. The strata are nearly flat; and, seen at intervals, they continue so for about six miles to the bridge on the Chateauguay River, in the first two miles of which the same two species of *Maclurea* are met with in several exposures, while the lithological character of the rock varies little the whole way. An exposure near the bridge displays *Pleurotomaria rotuloides* of Hall (a Trenton species). In beds of good limestone*, three miles farther east, and in the Caughnawaga quarry two miles beyond these, occur *Atrypa plena* and *Orthis pectinella*. Four miles farther on, at St. Louis Rapids, the rock contains nine species belonging to the Trenton formation. They are *Leptæna sericea, L. deltoidea, Orthis striatula, Lingula quadrata, Murchisonia bicincta, Glyptocrinus decadactylus, Echino-encrinites anatiformis, Calymene senaria, Isotelus gigas*, besides the genera *Stromatopora, Orthoceras*, and an unfigured species of *Encrinurus*. Beyond this the Utica slate appears below the St. Louis Rapids, and, crossing the St. Lawrence, can be traced along the shore of the Island of Montreal to the city, displaying *Triarthrus Beckii* and *Graptolithus bicornis* in many places.

Passing westward from the track-bed near the mouth of the Beauharnois Canal, the sandstone can be followed with little intermission for a distance of three miles up the St. Lawrence, where it becomes interstratified with calcareo-arenaceous layers; but at St. Timothy, three miles farther, sandstone beds, holding *Scolithus*, are still met with, and *Raphistoma* occurs in Calciferous Sandrock. For between four and five miles farther up the river the strata are concealed by drift, until reaching Grande Isle, where quarries expose good limestone beds, resting horizontally on others of an arenaceous character, and containing *Raphistoma* (two species), *Murchisonia, Euomphalus*, and *Leperditia canadensis*† (Jones, MS.), all unfigured; and at the head (western end) of the Beauharnois Canal, three miles farther up, besides *Raphistoma* there is a *Phacops*, allied to *P. Downingiæ*, and *Isotelus gigas* (the latter belonging to the Chazy limestone). All

* In a communication from Mr. Logan, dated at Montreal, July 6, 1852, it is directed that the boundary-line of the Chazy and Trenton limestones between the bridge on the Chateauguay River and the St. Louis Rapids should be removed to about a mile east of the position of Caughnawaga. It being too late, however, to correct the map, this emendation is here referred to. Mr. Logan also observes, with regard to the Island of Montreal and the district eastward of the Rivière du Nord, where the colour is made to die out, that he is now examining the unrepresented part of the country which is in the vicinity of this shading off, and he finds that the Chazy limestone comes nearly up to the Montreal Mountain (green on the Map), thus displaying very distinctly the trough of which the deepest part is under the Utica Slates of the White Horse Rapids.

By too much colour on the Map, the Trenton limestone of the White Horse Rapids is shaded off into the Chazy limestone of Montreal.

We have also to remark that the district coloured yellow should be designated as "Hudson River Group, covered with Tertiaries and Drift."

† Occurring also at Hawkesbury, Grenville, and Loucks Mills (wrongly spelt on the Map), on the Castor River.

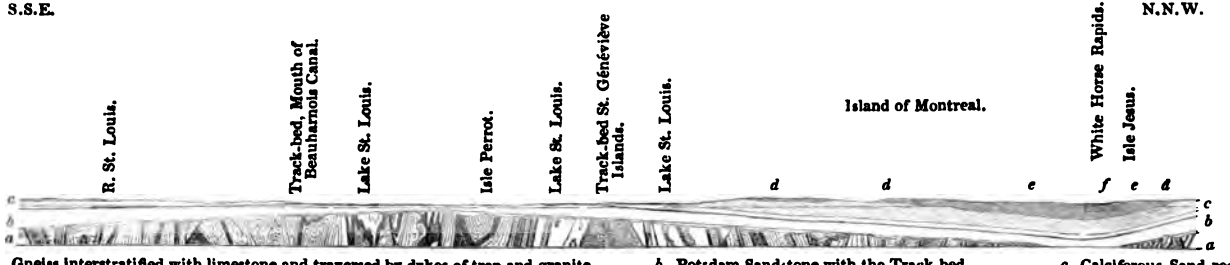
Fig. 1.—*Section from St. Louis Rapids to the Cedars Rapids.* Section No. 1 on the Map.

Horizontal Scale, 3 miles to 1 inch. Vertical Scale, 1 mile to 2 inches.

a. Gneiss. *b*. Potsdam Sandstone. *c*. Calciferous Sand-rock. *d*. Trenton Limestone. *e*. Utica Slates.

Fig. 2.—*Section from Isle Jesus to River St. Louis.* Section No. 2 on the Map.

Distance about 23 miles.



a. Gneiss interstratified with limestone and traversed by dykes of trap and granite.
b. Potsdam Sandstone with the Track-bed.
c. Calciferous Sand-rock.
d. Chazy Limestone.
e. Trenton, Black River, and Bird's-eye Limestones.
f. Utica Slates.

these localities, both to the east and west of the foot-prints, are included in the line of section given with last year's communication*.

Another of the track-bed localities is in the vicinity of Point Cavagnol, on the south side of the Lake of the Two Mountains, about fifteen miles from the locality near the mouth of the Beauharnois Canal. Both of these localities are on the western side of the axis of the flat anticlinal arch, formed by the projecting tongue of sandstone between Beauharnois and Mont Calvaire, as described in my former paper. To the westward of the tracks of Point Cavagnol the country is so covered with drift and forest, that no traverse, starting immediately from the bed, has been attempted in that direction beyond a few miles, in which no exposure was met with; but on the lake side of the tracks, and a short distance beneath them, a bed of red sandstone occurs.

The fourth new locality is on one of the islands of St. Génévière, between two and three miles east of St. Ann, at the upper end of the Island of Montreal. This spot is about seven miles from the Beauharnois village exposures, and, with them, is on the east side of the anticlinal axis. If a line be followed obliquely across the anticlinal from the Canal track-bed to that of St. Génévière Island, and pursued to the White Horse Rapids between the Islands of Montreal and Jesus, a little below Isle Bizard, coarser sandstones would come from beneath the Canal track-bed about a mile out in Lake St. Louis (see fig. 2, & Section 2 of the Map). They are represented by the sandstones and conglomerates of Cascade Point and Cascade Island close by, of which they would be in the strike. A thickness of 65 feet of these coarser strata can be made out at the Point, and they are probably as much below the track-bed. The traverse-line would cross Isle Perrot, which is all underlaid by the sandstone, and on reaching the track-bed of St. Génévière Island, not a mile on the north side of Perrot, we again find the rock marked by *Scolithus*, with which it is in some spots completely honeycombed to the depth of 3 feet, while it is also interstratified with thin irregular calciferous bands. St. Ann's Point may be considered in the strike of the St. Génévière Island, and here we still find the sandstone marked by *Scolithus*; while on Isle Perrot, opposite, there occurs a bed of red sandstone identical in character with that of Point Cavagnol, and angular fragments of the same strew the shore above St. Ann. Proceeding northwards, we find immediately behind the village of St. Ann's the outcrop of the Calciferous Sand-rock holding geodes of calc-spar; and in a quarry to which resort has been had for building-stone we meet with a *Murchisonia*, like *M. gracilis*, but flat in the whorls, a *Pleurotomaria*, like *P. subconica*, but more depressed, *Leperditia Anna* (Jones, MS.), and *Orthoceras*. Further on the road, about half a mile, a *Raphistoma* occurs in calcareo-arenaceous beds, which with thin geodes of calc-spar are met with in several places farther on. We then, in a low escarpment, come upon a rock composed almost entirely of *Atrypa plena*, a species characteristic of the Chazy Limestone. The rock usually affords good building-stone as well as

* *Loc. cit.* p. 249, and repeated here (fig. 1 & Section 1. of the Map).

stone for lime-burning, and it has been much quarried at the village of St. Génévière, just opposite the mid-length of Isle Bizard. The White Horse Rapids are situated about three miles to the east, and here, on both sides of the Rivière des Prairies (a branch of the Ottawa), black limestone-beds, lying in the form of a shallow trough, and displaying fifteen species of Trenton and one of Chazy fossils, are surmounted by black bituminous shales holding *Triarthrus Beckii* and *Graptolithus bicornis* of the Utica Slate, while loose fragments of black limestone (possibly Trenton limestone) at no great distance are characterized by *Leperditia gracilis* (Jones, MS.) and *Serpulites*. The Trenton Limestone of this part is probably continuous with that of the south side of Montreal Island, where, about three miles W. of Lachine, on the road to St. Ann, fifteen Trenton species have been met with; and in the quarries of Point St. Claire, six miles nearer St. Ann, we get five species characterizing the Bird's-eye Limestone, with one usually found in the Chazy, and four given by Hall to the Trenton.

Point St. Claire.*

Favistella (Columnaria) alveolata	Trenton.
Stictopora acuta	,,
Leptæna sericea	,,
—— alternata	,,
Pleurotomaria umbilicata	Bird's-eye.
Murchisonia perangulata	,,
Modiolopsis obtusa	,,
Favosites alveolaris?	,,
Phytopsis cellulosa	,,
Atrypa plena?	Chazy.

Three Miles above Lachine.

Favosites (Chætetes) lycoperdon	Trenton.
Orbicula lamellosa	,,
—— terminalis?	,,
Leptæna sericea	,,
—— deltoidea; plentiful	,,
Orthis (testudinaria) striatula (Emmons)	,,
—— pectinella	,,
Modiola (Tellinomya) anatiformis?	,,
Bellerophon bilobatus	,,
Oncoceras constrictum	,,
Cyrtolites trentonensis	,,
—— ornatus	,,
Calymene senaria; plentiful	,,
Isotelus gigas	,,
Leperditia (L. Canadensis?), a species ¼ inch long.	
Orthoceras.	
Serpulites, allied to S. dispar (Salter).	
Conularia.	
Encrinurus, the same as at White Horse Rapids.	

White Horse Rapids.

Favosites (Chætetes) lycoperdon	Trenton.
Stictopora acuta	,,

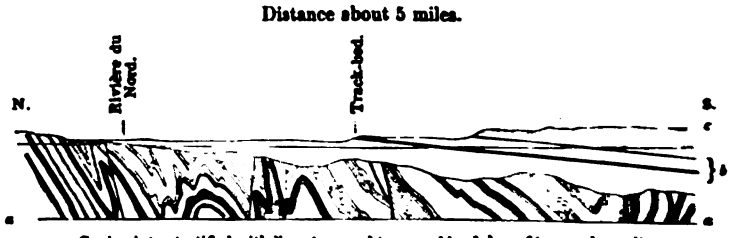
* These lists, and the names of the other fossils mentioned in the paper, are furnished by my friend Mr. Salter, of the Geological Survey of Great Britain.

Leptæna sericea; plentiful	Trenton.
—— deltoidea; very abundant	,,
—— alternata	,,
Orthis (testudinaria) striatula	,,
—— lynx	,,
—— pectinella	,,
—— bella rugosa?	,,
—— disparilis	,,
Echino-encrinites anatiformis; plentiful	,,
Glyptocrinus decadactylus	,,
Calymene senaria	,,
Isotelus gigas	,,
Atrypa plena	Chazy.

Encrinurus, with punctured cheeks.
Raphistoma, two undescribed species, found also at Poquettes Rapid, Allumettes Island.
Atrypa, allied to A. extans.
—— or Rhynconella, allied to A. navicula, but with a sinus in the front of the larger valve.
Fenestella, Lingula, Bellerophon, Orthoceras.

The fifth new locality in which the foot-prints occur is on the Rivière du Nord, in the Seignory of Argenteuil, along which river the sandstone again crops out, and runs in a W.S.W. direction almost in a line with the Valley of the Ottawa (see Map, Sect 3; and fig. 3). The

Fig. 3.—*Section across the Rivière du Nord in the Seignory of Argenteuil.* Section No. 3 on the Map.



dip of the strata is here a little more decided than we have yet had it, the inclination being south at an angle of about 4°; and in the space of a mile and a quarter the stratigraphical relations of the rocks can be well made out. We have first the gneiss and its interstratified limestone; then the sandstone, not seen in actual contact with it, but forming an escarpment of between 30 and 40 feet in height, between which and the gneiss there is a flat sandy valley, varying in breadth from one quarter to half a mile, in which the stream winds its course. The sandstone has been traced thirteen miles consecutively to the eastward, and is known far beyond; and where a transverse section was measured the track-bed occurs at the top of the escarpment at a height of probably 100 or 200 feet over the gneiss. South of the outcrop of the track-bed, about 330 yards over a flat

surface, another escarpment rises to the height of 70 feet. The white sandstone, perforated with *Scolithus*, is seen at the base, interstratified with calcareo-arenaceous beds for about 25 feet up, and these calcareo-arenaceous beds, holding geodes of calc-spar, compose the remainder of the rise. About 300 yards further, after a very gentle slope, there is a smaller step, composed of the same description of calcareous sandstones, and from this a level surface, of about a quarter of a mile broad, in which similar strata are seen once, reaches a small rise of 5 feet, composed of an arenaceous limestone, which is quarried for burning. In the quarry occurs *Ophileta levata* of Vanuxem (a Calciferous Sand-rock species) and *Raphistoma* (the same as that of St. Ann's section); and the general dip in the section is such as to leave no room to doubt the place of the track-bed, which would be about 160 feet beneath the limestone.

Farther south this line is covered up by sandy drift for several miles, but, if we go about five or six miles to the westward, and again starting from the gneiss, take a course at right angles to the strike (Section 4 of the Map), three and a half miles will bring us to a two-feet bed of good limestone. This rock, from its having been quarried for lime-burning in several places, has been followed from Carrillon to Grenville (thirteen miles). The dip of the limestone from its outcrop to the river (two miles) is about 75 feet in a mile. That it overlies the beds of the previous section is not considered uncertain; from the paucity of exposures, however, between it and the gneiss, and the increased dip near the gneiss, it is not easy to determine its relative position. It may be at least 150 feet higher; for there are seen in some of the naturally exposed sections of the Ottawa very nearly 100 feet of underlying calcareous claystone, weathering more or less yellow or brown, and in some parts bituminous and in others arenaceous, and often presenting in the latter case geodes of calc-spar and heavy-spar; and none of these beds appear in the Rivière du Nord section. Immediately beneath the 2-feet limestone there is a singular and extensively spread concretionary layer, in some large exposures of which, surfaces of half an acre show these concretions, consisting of concentric layers, cut in half and closely packed together, some of them being 2 to 3 feet in diameter. The limestone bed is fossiliferous, and displays *Maclurea sordida* (a Calciferous Sand-rock species), *Pleurotomaria nodulosa*? (a Bird's-eye species), *Murchisonia bicincta*, and another species, an *Atrypa* allied to *A. extans*, *Raphistoma*, *Turbo*, *Modiola*, *Orthoceras*, *Leperditia Canadensis* (Jones, MS.), and *Beyrichia Logani** (Jones, MS.), in abundance, and a new species of *Paradoxides*†; and at a short distance above the bed there are about 50 feet of sandstone, with bands of green shale, holding a vast collection of Fucoids, of which a bilobated species is most conspicuous. Some of the sandstone beds are

* Occurring also at Hawkesbury.

† The head is not perfect, but, from the general character of the glabella and eyes, Mr. Salter has little doubt that it belongs to *Paradoxides*. That genus, however, has not yet been noticed in America.

porous and moderately fine-grained and yield good fire-stones, while others are coarse, and, in addition to quartz-pebbles, hold a multitude of phosphatic nodules, mingled with small fragments of what appear to be *Lingulæ*. At Grenville, where these beds have been most exposed by the cutting of the canal, they are found to cross the Ottawa to Hamiltonville in Hawkesbury, and to extend half a mile back from the river; and half a mile beyond them a low escarpment presents the base of the Chazy Limestone, composed, as in the St. Ann's section, almost entirely of *Atrypa plena*. In this rock also small phosphatic nodules exist in some abundance, a few of which hold small fragments of shells.

Phosphatic nodules have also been met with higher up on the Ottawa, at the Allumettes Rapids, in a conglomerate bed occupying the same stratigraphical position as the Grenville beds, but there resting on the gneiss. Great numbers of one large species of *Lingula*, very like *L. parallela* of Phillips, and a few of *Pleurotomaria* or *Holopea*, occur with the nodules. Every one of the *Lingulæ* is imbedded in a coating of the phosphate, and in one instance a fragment of a *Lingula* was found lying across the length of the nodule. The specimen of *Pleurotomaria* is a phosphatic cast of the interior of the shell.

I may here mention also, that much higher in the Lower Silurian series of strata, in fact, just above the Hudson River Group, but considerably removed from this locality, phosphatic nodules occur in great abundance, and one of them, obtained at Rivière Ouelle, on the south side of the St. Lawrence, seventy-five miles below Quebec, whence the limestones and sandstones in which they occur are traceable to Point Levi, opposite the Capital, so much resembles a fragment of a cylindrical bone, and is so like bone in chemical composition, that I have had it sliced, fully expecting it would show bony structure. This, however, is wanting; but the specimen suggests the inquiry, whether, confined in its stony mould, any chemical action may have been exerted to obliterate its original structure without destroying its form.

I append to this paper the analyses, with which my friend Mr. Hunt, the chemist attached to the Canadian Survey, has furnished me, of four phosphatic specimens, two of them from the Rivière Ouelle, one of these being the bone-like fragment; the third is from the Chazy beds of Hawkesbury, and the fourth, from the Allumettes Rapids. By these analyses it will be perceived that the specimens yield from 36 to 67 per cent. of phosphate of lime, and that they all, on being heated, give out ammonia and an animal odour like that of burnt horn. One of the Grenville nodules was tested for phosphate of lime, and found to contain it largely, and it also gave out the animal odour, but it was not quantitatively analysed.

Examinations of Phosphatic matters, supposed Bones, and Coprolites, occurring in the Lower Silurian Rocks of Canada. By T. S. HUNT, Chemist to the Canadian Geological Survey.

Supposed coprolite from Lac des Allumettes, in sandstone, with *Lingulæ*.—Porous, having a specific gravity of 2·875. By ignition gave out water and an animal odour like burnt horn, and the vapours temporarily browned turmeric paper. It dissolved in acids with slight effervescence, leaving a residue of pure granular silica, which was in grains distinctly visible on fracturing the mass. 100 parts gave on analysis—

Phosphate of lime (PO5, 3CaO)..	36·38
Carbonate of lime.....	5·00
Magnesia .. Oxide of iron } by loss.....	7·02
Insoluble siliceous grains.....	49·90
Volatile	1·70
	100·00

Another fragment gave 42·54 of siliceous matter. The brown matter replacing or filling the *Lingulæ* in the bed was found to be phosphate, with a little carbonate of lime and animal matter, with siliceous particles.

No. 2. Coprolite from Chazy limestone, Hawkesbury.—Yellowish within, but penetrated for a little depth by a blackish matter (probably infiltrated oxide of iron). The powder when heated in a tube gives off so much ammonia as to produce white fumes with acetic acid. 100 parts gave—

Phosphate of lime	44·70
Carbonate of lime.....	6·60
Carbonate of magnesia	4·76
Oxide of iron	8·60
Insoluble siliceous matter	27·90
Volatile matter (water in part)	5·00
	97·66

No. 3. Fragment of supposed cylindrical bone from Rivière Ouelle.—It was blackish brown and compact. Within it was filled with earthy matter (the imbedding sandstone), which was not entirely detached before the analysis. Its analysis gave, for 100 parts, as follows:—

Phosphate of lime	67·53
Lime .. Magnesia } as carbonates and fluorids	2·44 / 1·65
Oxide of iron	2·95
Insoluble (in part, the adherent matrix)	21·10
Volatile.....	2·15
	97·82

The loss arises from the carbonic acid which is not here represented as combined with the excess of lime and magnesia.

The compact ivory-like fragment from Rivière Ouelle had a sp. gr. of 3·035 to 3·150. It gave out ammonia and water with an animal odour when heated, and with sulphuric acid the vapours corroded glass, indicating a fluorid. It contained a larger proportion of carbonate of lime and magnesia, and more oxide of iron, than the hollow bone from the same locality. 100 parts of it gave—

Phosphate of lime	40·34
Carbonate of lime and some fluorid	5·14
Carbonate of magnesia	9·70
Oxide of iron, with a little alumina and manganese	12·62
Insoluble siliceous matter	25·44
Volatile	2·13
	95·37

The analysis is defective from a loss of over 4 per cent., but the quantities actually found show sufficiently well the composition of the substance where scientific accuracy is not essential.

Before returning to the foot-prints, I would further state, on the subject of phosphatic nodules, that last season my associate, Mr. Murray, in examining the rocks on which the Lower Silurian unconformably rests in the Johnstown District, met with altered conglomerates interstratified with limestone not distinguishable from the highly crystalline rock which is interstratified with the gneiss; and associated with the quartz-pebbles of the conglomerate are soft white nodules containing phosphate of lime. In the beds of the crystalline limestone, separating the masses of gneiss, imperfect crystallizations of phosphate of lime are of very frequent occurrence. They are usually small, but in some parts they become large and so thickly disseminated as to give the rock an economic value. On Lake Huron the Lower Silurian group rests unconformably upon a siliceous series with only one known band of limestone, of about 150 feet thick, with leaves of chert in abundance, but as yet without discovered fossils. This series is supposed to be of the Cambrian epoch. It comprehends the copper-bearing rocks of that district, and with its igneous interstratified masses has a thickness of at least 10,000 feet. The gneissoid group, of which mention is made, is probably still older than this. Its conditions appear to me to make it reasonable to suppose that it consists of aqueous deposits in an altered state, and the origin of the phosphatic nodules and crystals in some of its members, with reference to a possible connexion with life in such ancient strata, becomes a question of great interest.

Having shown, I hope conclusively, the stratigraphical relations of the track-beds, I have only farther to state that, with the view of submitting to competent authority as large an amount of evidence as

convenient to illustrate the nature of the animal or animals by which the foot-prints were impressed, I have brought over and temporarily placed in the Museum of the Society the original slab of sandstone, 12½ feet in length, from which the casts of last year's communication were taken (No. 7 of Prof. Owen's description); a second slab of the original stone, from Mr. Henault's field, measuring 8 feet (No. 3 of Prof. Owen's description); and a third slab, with two tracks and ripple-mark upon it, from the Island of St. Génévière. These are accompanied by about 100 slabs of plaster-casts, taken from various tracks as they are naturally exposed in the field. Adding one track to another they measure about 350 feet. Two of the casts are from tracks immediately near the one first discovered, and one of them shows the groove running out of the centre (No. 4 of Prof. Owen's description). The remainder are from Henault's field. In it four areas are comprehended within a distance of four chains, three of which are exhibited in their true relation to one another in Pl. VII. A, B, C; and each of these is displayed on a larger scale, 3 inches to 16 feet, in Pl. VIII. A, B, C.

In Pl. VIII. A. there are ten tracks, seven of them on a smooth-surfaced bed, which has been rubbed by ice moving in a direction S. 40° W. These tracks are indicated by lines of different colour, and are numbered 1 to 7. Their measurements are,—

	ft.	in.		in.		
1.	6	0	long by	5	wide.	
2.	10	3	„	5¼	„	
3.	28	6	„	5½	„	(No. 5 of Prof. Owen's description.)
4.	24	6	„	4¼	„	
5.	8	6	„	5½	„	
6.	6	3	„	5	„	(No. 1 of Prof. Owen's description.)
7.	12	0	„	5	„	(No. 6 of Prof. Owen's description.)
	96	0				

On a surface 2 inches lower, showing ripple-marks (the ridges of the ripple-mark running N. 75° E.), there are two tracks, numbered 9 and 10, measuring,

	ft.	in.	
9.	5	4	long,
10.	4	6	„
	9	10	

And there is another, on a surface still lower by about 1 inch, but showing no ripple-mark,

	ft.	in.		in.	
8.	4	6	long by	5½	wide.

Pl. VIII. B. shows seventeen tracks, twelve of which are on a smooth surface, which has been rubbed by ice moving in a S.W. direction. They are numbered 1 to 12, and measure

	ft.	in.		in.		
1.	3	0	long by	5	wide.	
2.	4	6	,,	5½	,,	
3.	4	0	,,	4	,,	
4.	5	3*	,,	5	,,	
5.	3	8	,,	4½	,,	
6.	5	5†	,,	5½	,,	(No. 2 of Prof. Owen's description.)
7.	11	8	,,	5½	,,	
8.	12	0	,,	5¾	,,	
9.	12	0	,,	6	,,	
10.	18	0	,,	5¾	,,	
11.	10	0	,,	6	,,	
12.	18	0‡	,,	6½	,,	(No. 3 of Prof. Owen's description.)
	107	6				

The remaining five, numbered 13 to 17, are upon a ripple-marked surface, the ridges of the ripples running in the direction N. 71° E., and this surface is 2 inches below the smooth one. The measurements are—

	ft.	in.		in.	
13.	14	6	long by	6	wide.
14.	3	3	,,		
15.	15	3	,,	4½	,,
16.	20	4	,,	4	,,
17.	8	3	,,	5	,,
	61	7			

Pl. VIII. C. shows six tracks, which are represented by coloured lines without numbers. One of them is very narrow, not exceeding three-quarters of an inch in breadth. Their measurements are—

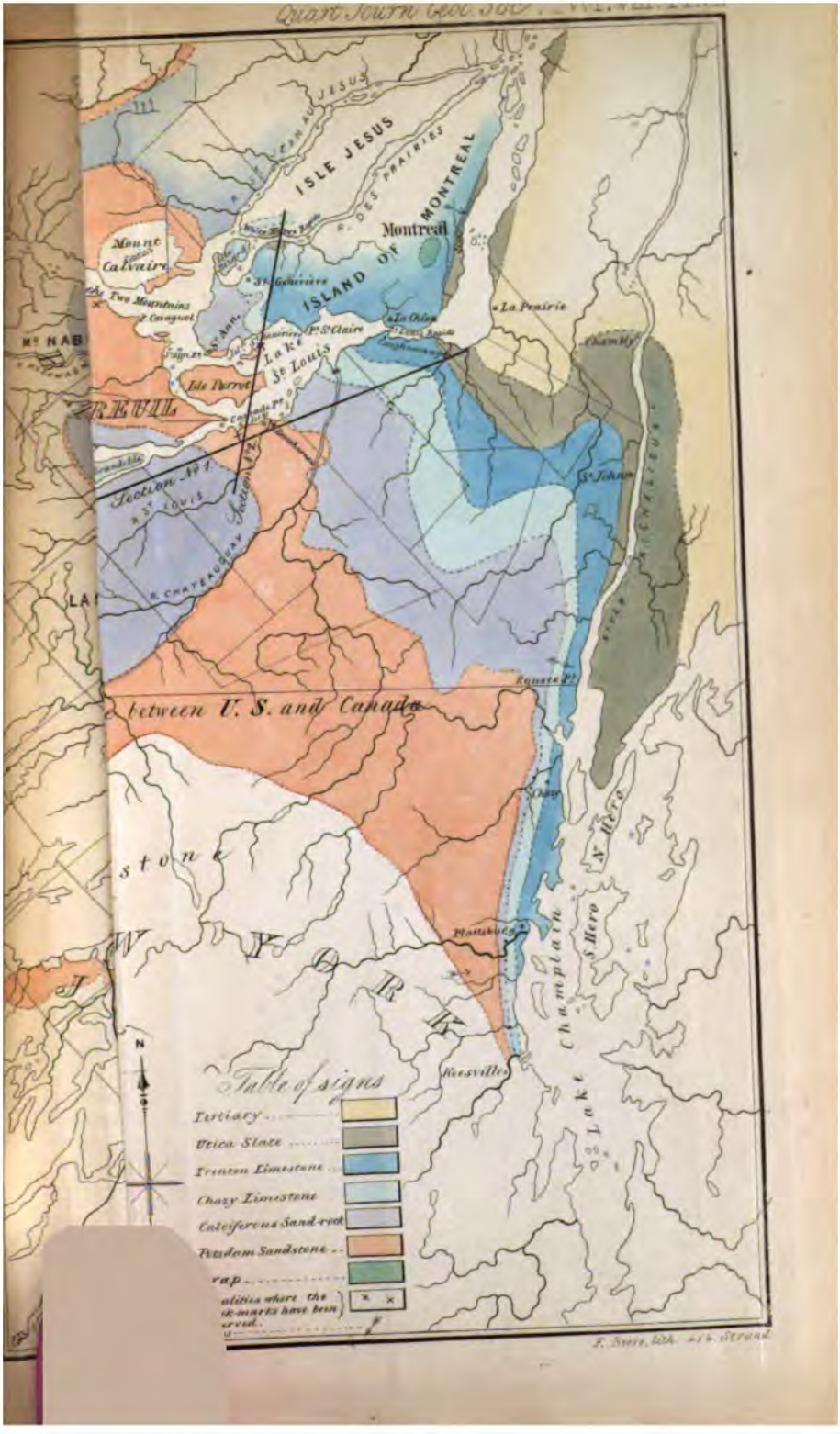
ft.	in.		in.	
9	6	long by	4½	wide.
3	0	,,	5½	,,
3	6	,,	5½	,,
1	0	,,	5½	,,
1	0	,,	0¾	,,
18	0			

The tracks are upon a smooth surface (marked *b*), which, like the other smooth surfaces, has been rubbed by the ice. On the same surface there is ripple-mark, the natural edge or termination of which is seen, and by it the tracks are obliterated. Three of them come up to the edge of the ripple, and are not traceable upon it. From the general line of the edge a part projects, like a spur or triangle, which is marked across by the ripple up to the apex, as if the cause producing the ripple had reached that far and no farther. The part lettered *d* also shows ripple-marks, and is 6 inches higher than the surface marked *c*, which runs on below it, and while the direction of the ripple-lines on *d* is S. 53° E, those on *c* run S. 80° E. On the

* Rather less of this track appears in the plan than on the plaster-casts.

† In the plan this track extends further than on the plaster-casts.

‡ A portion of this track, to the extent of 87 feet, on the sandstone slab, is temporarily placed in the Society's Museum by Mr. Logan.


ISLE JESUS
ISLAND OF MONTREAL
Montreal
Mount Calvaire
Two Mountains
Lake St Louis
Isle Perrot
REVIL
Section 4
Section 3
between U. S. and Canada
La Prairie
St Johns
Rouses Pt
St Chas
St Hero
Champlain
Lake
Montebello
Rouseville
Table of signs
Tertiary
Utica Slate
Trenton Limestone
Chazy Limestone
Calciferous Sand-rock
Potsdam Sandstone
Trap
F. Sears, lith. 214 Broad

part lettered *a* there is also ripple-mark. It is an inch or two below *b*, and the ripple-ridges on it run N. 15° E. The inference which I wish to draw from these facts is, that the ripple-ridges on succeeding surfaces, only a few inches above one another, being in different directions, and the limit of the producing cause of the ripple being indicated in one example, it appears probable that the ripple was produced by tide rather than by a current in deep water; that in the same area one part of the surface was dry when the wave was acting close by on another part; and that the direction of the wave was towards the apex of the triangular space.

The fourth area, of which no plan is given, is removed a few yards to the east of that lettered C in Pl. VII., and on the casts of this surface it will be seen that there are ten tracks, measuring—

ft.	in.		in.	
6	0	long by	5½	wide.
10	6	,,	5½	,,
8	0	,,	5	,,
2	5	,,	5½	,,
5	9	,,	6½	,,
2	7	,,	4½	,,
6	9	,,	5½	,,
5	7	,,	5½	,,
4	8	,,	4	,,
4	0	,,	5	,,
56	5			

The geological importance given to these tracks by the opinion expressed by Professor Owen in regard to the specimens produced last season, has induced me to spare no pains in bringing evidence to bear on the subject; and the materials having been submitted to the examination of the Professor, he has kindly undertaken to lay before the Meeting a description of them.

At the Evening Meeting, March 24, M. E. Desor exhibited an engraving of a slab with Foot-prints bearing a general resemblance to *Protichnites*. These Tracks are from the vicinity of the Niagara Falls, and belong to the "Clinton group." Prof. Owen has supplied the following note on these Foot-prints.

The plate exhibited by M. Desor gives a view of a series of prints on each side a median track, of about 18 inches in extent. The foot-prints on one side of the median track are in successive groups of three prints, the two next the track being most approximated. Only the pairs of prints corresponding to those median pairs are shown on the other side of the track. The plate gives no indication of successive groups of three sets of prints; but it would be unsafe to rely upon it for the precise character of the impressions.

[*Note.*—The casts of surface A, Pl. VIII. (including the tracks, *P. 7-notatus*, *P. lineatus*, and *P. alternans*), together with characteristic impressions of the remaining species, will be deposited in the British Museum.]

2. Description *of the* Impressions *and* Foot-prints *of the* Protichnites *from the* Potsdam Sandstone *of* Canada. By Prof. Owen, F.R.S., F.G.S. &c.

[Plates IX. to XIV. A.]

Of the extensive series of foot-prints found under the circumstances described in the preceding communication, the originals of some and good plaster-casts of more have been brought over with much labour and expense by their discoverer, Mr. Logan, and of these I have selected the best-marked and most intelligible portions for the following descriptions.

1. *Protichnites septem-notatus.* Pl. IX.

The subject, which for the convenience of reference I have so named, consists of a series of well-defined impressions, continued in regular succession along an extent of 4 feet; and traceable, with an inferior degree of definition, along a further extent of upwards of 2 feet.

These impressions (see Plan, Pl. VIII. A. 6) are represented by plaster-casts.

In the first-selected extent of 4 feet there are thirty successive groups of foot-prints on each side of a median furrow, which is alternately deep and shallow along pretty regular spaces of about 2¼ inches in extent. The number of prints is not the same in each group; where they are best marked, as in Pl. IX. 1 *L*, we see 3 prints in one group, *a*, *a'*, *a''*, 2 prints in the next, *b*, *b'*, and 2 in the third, *c*, *c'*, which is followed by a repetition of the group of 3 prints, *a*, *a'*, *a''*. But, in some instances, the outer print of the third set is divided, as at 1 *R*, *c'*, *c''*, making the numbers in the three successive groups 3, 2, 3, instead of 3, 2, 2: the three groups of impressions are, however, notwithstanding this occasional variety, recognizably repeated in succession along the whole series of tracks on both sides of the median groove*.

The principal foot-prints are disposed in pairs, placed with different degrees of obliquity, in each of the three groups, towards the median track; the innermost print in the second, *b*, and third, *c*, pairs, which are best marked, being usually rather more than half the size of the outer print, *b'* and *c'*.

The two foot-prints of the same pair are a little further apart from each other, in the three succeeding pairs, as at *a'*, *a''*, *b*, *b'*, *c*, *c'*, especially in the second and third groups of each set; the two forming the pair *a'*, *a''* again approximating in the next series, and the pairs *b*, *b'* and *c*, *c'* diverging in the same direction and degree; and this alternate approximation and divergence is repeated throughout the entire series of the present tracks.

* Should these descriptions express more or less than is shown in the Plates, the reader will be kind enough to bear in mind that they were penned after repeated examinations of the originals by varied applications of artificial and natural lights, and express the sum of the results of such comparisons extended over the entire series of tracks; whilst the able artist has given the effects of one light and shade only, as seen on one portion of the track.

But what strikes the ichnologist, heretofore conversant chiefly with the foot-prints of bipeds or quadrupeds, is the occurrence in the present series of the third impression, *a*, which complicates the most approximated pair, being placed in front and a little to the inner side of the innermost impression, *a'*, of that pair. The superadded impression, *a*, is about the same size as the innermost in each pair, the average diameter of that impression being 5 lines.

Taking this view of the impressions, it appears that, whilst the innermost in each pair, *a'*, *b*, *c*, are of equal size, the outermost, *a''*, *b'*, *c'*, 1 *L*, progressively increase in size, from the most approximated to the most divergent of the three pairs; that of the first, *a''*, being narrow in proportion to its length, that of the second, *b'*, as broad as long, and the outermost, *c'*, *c''*, of the third pair being oblong, but larger than that in the first pair. In some places where the most approximated pair of impressions, *a'*, *a''*, are deeply marked, they are complicated by a fourth shallow and very small pit, *a'''*, 2 *L*, midway between the third, *a*, and the outermost, *a''*, of the pair of impressions.

The deepest parts of the middle track usually occur between the second, *b*, *b'*, of each of the three groups of foot-prints.

The first pair of impressions, *a'*, *a''*, are included within a space of 1 inch 3 lines in diameter; the third pair within a space of 1 inch 9 lines in diameter. The longitudinal extent of the three groups of impressions, measured along the outermost, averages 3 inches 6 lines, and along the innermost 3 inches 3 lines: the extreme extent of the three sets of impressions averages 4 inches. The transverse interval between the innermost impressions, *a*, *a*, of the first pair is 3 inches, and between those of the third pair, *c*, *c*, 2 inches, measured from their innermost borders. The distance between the two outermost impressions of the first pair is 5 inches, and it is the same between the corresponding impressions of the third pair, measured from their outer borders; so that a line drawn along the outer margin of the impressions of one side would be parallel to the line drawn along the same parts on the opposite side, the difference in the distance from the midspace being presented by the innermost impressions.

The average breadth of the median groove is 5 lines, its depth at the deepest parts between 1 and 2 lines; the regular alternation of the deep and shallow parts of the median impression indicates the part that made it to have been alternately raised and depressed, an alternation which might affect a tail as well as the trunk, but is more likely to have affected the latter in an undulating mode of progression.

There are no clear or unequivocal marks of toes or nails on any of the impressions which form the lateral pairs or triplets. Their margins are not sharply defined, but are rounded off and sink gradually to the deepest part, which is a little behind the middle of the depression. There is a slight variation in the form and depth of the answerable impressions, but not such as to prevent their correspondence being readily appreciable through the whole of the extent here described; that is to say, the innermost of each of the three pairs here described as first, *A*, second, *B*, and third, *C*, may be identified with the corresponding innermost impression on the opposite side and

with the same impression of the same pair in the three preceding and the three succeeding pairs.

This power of determining the homologies, so to speak, of the several impressions is a strong evidence of their having been made by the successive application of the same instruments; whilst the equal distances at which they recur proves them to have been made in regular succession, as in the ordinary progression of an animal walking by means of limbs.

The question next to be resolved is,—how those instruments were disposed in the body of the creature that made and left the impressions?

It cannot be supposed that two limbs, answering to the fore and hind legs of a quadruped, could have made impressions so different in form and in their degrees of approximation as we see in each pair of the series of three sets on one side. In a quadruped we are accustomed to see the successive pairs of the same side resembling each other, the difference in the two impressions of such pairs indicating the difference between the fore and hind feet of the side to which they belonged; but in the present series of impressions each pair in the successive series of three so differs from the other two pairs in the form and size of the impressions, and their degree of divergence, as to render it scarcely possible to suppose that they could have been formed, either along the inner or the outer series of impressions, by successive steps of the same limb; and, were it contended that the animal by some peculiarity of gait more and more approximated its fore limbs in making three successive steps, and then divaricated them to commence another series of three steps, on the supposition that the inner impressions were formed by the same pair of fore limbs at each series of three steps, the difficulty would still remain of accounting for the third superadded impression, *a*, on the hypothesis of their being formed by a quadruped, with the additional difficulty of the difference in shape and size of the outer impressions of the same three pairs.

The first or most approximated pair, *a'*, *a''*, in each set of three pairs of impressions are the most equal in size. In the second pair, *b*, *b'*, which are nearly equally approximated, the outer impression is manifestly larger and broader than the inner one. In the third and most divergent pair, *c*, *c'*, the outer one is still larger, in length as well as in breadth, and is occasionally subdivided. Now, as the first pair in each series of three, *A*, 1 *L*, plainly answers to the same pair in the next series of three, *A*, 2 *L*, and the like in regard to the second pair and the third pair, it follows that the same instruments must have made the first pair in each of the three pairs, and so of the second and of the third pairs; or, in other words, each pair in a series of three must have been made by different members, or divisions of members; and the same must be inferred in respect to the small impression, *a*, which is superadded to the first pair in each triplet: whence it may be concluded either that the animal had seven pairs of ambulatory limbs, or that it had three pairs, of which two were bifid and the third trifid at the impressing extremity.

The impressions which are so clearly marked in the extent above described are continued less distinctly but uninterruptedly for more

than 6 feet. The most constant of the small impressions are those which are nearest the median track, *c*, and which have been described as the innermost of the third pair, but which first arrest the eye as superadded foot-marks, occurring pretty regularly at intervals of from 4 inches to 4½ inches along the whole track.

There are three other series of tracks referable to the *Protichnites 7-notatus*.

2. *Protichnites octo-notatus*. Pl. X.

The series of foot-prints, here described as the *Protichnites 8-notatus*, extends for 5 feet 5 inches along a surface of hard sandstone, which has been rubbed by the ice. This track is represented by plaster-casts. It is seen on the Plan, Pl. VIII. B. 6. In this series the impressions of the feet are deeper and the median track is much fainter, yet it continues to show the alternately deep and shallow character, its traces being visible at regular intervals, which are, however, longer than those that divide the deeper parts of the same groove in the first-described series of impressions.

In the present series the small innermost impressions, *c*, are repeated at intervals of 5 inches; the distance between the right and the left of these impressions is 2 inches, being less than half their longitudinal interval; whereas in the former slab the transverse interval is exactly half the longitudinal one.

The larger and more exterior depressions present also a somewhat different arrangement from those first described. Where they are most clearly and regularly impressed it is as follows:—on the outside of the small innermost impression, *c*, there is a pair of larger impressions, *c'*, *c''*, closely approximated one behind the other, in the direction of the track, the longitudinal extent of this pair of impressions being 1 inch. The next pair of impressions, *b*, *b'*, answering to the middle pair before described, and here noticed in the contrary or retrograde course, are placed nearly transversely and are wider apart than the longitudinal pair, the innermost being the largest, and the diameter of the pair 1 inch 8 lines. Then follow three impressions, *a*, *a'*, *a''*, forming an inequilateral triangle, with a broad base turned inwards and the apex outwards, the impression forming which (*a''*) is the largest of the three, although they are of nearly equal size, having a diameter each of about half an inch. These three impressions answer to the three, *a*, *a'*, *a''*, Pl. IX., which have been described as forming the first pair of impressions with the accessory impression in the *Protichnites 7-notatus*; but the three are here so distinct and remote that the pair could only be chosen arbitrarily. The middle or second pair, *b*, *b'*, answers to the same in the impressions first described, with the difference of direction above noted: the third pair differs in the more constant and complete division of the larger outermost impression into two pits, *c*, *c'*. In none of these impressions are there distinct and unequivocal traces of claws or digital divisions; they seem rather to have been impressed by one limb, or division of a limb, terminating in a hard, obtuse, subangular point.

The arrangement of the impressions just described is repeated with little modification throughout this series of tracks; that is to say, taking them in the order in which those of the first series were de-

scribed, we have the group of three impressions, *a*, *a'*, *a''*, the transverse pair, *b*, *b'*, and the widest pair, *c*, *c'*, in which the outer and larger impression is divided into two, *c'*, *c''*.

Neither in this nor in the preceding series does any impression appear to be modified or in any degree obliterated by the print of another foot coming into the same place.

The median interval between the right and left of the first pit in the group of 3 impressions, *a'*, is 3 inches 9 lines; between the two pits in the same sets forming the apex of the triangle, *a''*, 4 inches 8 lines, and between the third, *a*, 3 inches 2 lines. These measurements are taken from the inner border of the right and left impressions respectively. The interval between the innermost, *b*, of the transverse pair of impressions is 3 inches 2 lines, and between the outermost, *b'*, from their outer borders 5 inches 8 lines: the interval between the longitudinal pairs, *c'*, *c''*, from their outer border is 5 inches 3 lines. The length of each series of three sets of impressions is from 5 inches to 5 inches 3 lines, and this distance is very regularly preserved throughout the series of tracks. Thus each series presents eight distinct impressions on each side, 1 *L*, 1 *R*, and tallying impressions of each of the eight can be determined in each successive series, 2 *L*, 2 *R*.

From this it is to be inferred that they were made by the same parts respectively; that is, that the impressions were repeated by the same limbs or impressing instruments at each successive series. Consequently if we regard each series as indicating the nature of the individual that impressed them, we must conclude it to have possessed either eight pairs of impressing instruments, or three pairs of limbs so divided as to leave 3 prints, 2 prints, and 3 prints in longitudinal succession on both the right and the left sides, and sufficiently long and flexible to make a step co-extensive with the space occupied by the entire series of such limbs; these impressions severally presenting characters so distinct in the same series of *A*, *B*, *C*, as to forbid the conclusion that they were made by the same instruments differently applied at regularly alternating intervals or distances in such series.

We have clearly, therefore, indications of the same kind or genus of animal in the present, as in the preceding series of tracks, but the difference in the proportions and arrangements of the individual impressions in the determinable groups indicates a difference of species. There are two other series of tracks of the *Protichnites* 8-*notatus* repeating very recognizably the characters above described.

3. *Protichnites latus*. Pl. XI.

A slab of the sandstone 8 feet long* by 2 feet wide shows three series of the impressions, two extending lengthwise and crossing each other very obliquely, and the third crossing both the others transversely. In the track which traverses the whole length of this slab the impressions of the feet are deeper and larger, whilst the median

* This track has a still greater extension on the plaster-casts taken from the sandstone-surface of which the slab here referred to is a portion. See the Plan, Pl. VIII. B. 12.

impression is much shallower and fainter than in the foregoing footprints, but it still shows the alternate deep and shallow parts. Although the impressions are less regular than in the before-described series, and the small innermost ones are less recognizable, yet they are discernible in certain parts, as at *c*, *c*, and they, in like manner, mark the boundaries of three sets of impressions on each side of the median one.

The first set consists of a pair, *a'*, *a''*, of nearly equal impressions, with occasional indications of a third print forming an inequilateral triangle. The second set of impressions is a transverse, more widely parted, pair, *b*, *b'*, the innermost being the smallest, the outermost the largest and sometimes, as in 1 *L*, divided into two, which are, however, included in a common circumference. Then that impression, *c'*, *c''*, which has been described as the outermost of the pair to which the small innermost impression, *c*, belongs, is very large and more distinctly bilobed than the outermost of the preceding pair, and its long axis is turned at right angles to that of the preceding outermost impression. The longitudinal extent of the three sets of impressions on one side is 5 inches. The transverse interspace between the two small innermost impressions, *c*, *c*, is 2 inches 2 lines, between the outermost, *a''*, *a''*, of the three sets of impressions from their outer borders 7 inches. The general resemblance of these successive series of three sets of impressions with those of the better-defined tracks before described leave no doubt of their having been made by the same genus of animal, but it would seem to be by a different species having a body broader in proportion to its length.

The sandstone allows a character of the lateral impressions to be seen which was not so distinctly recognizable in the casts, namely the great depth and angular figure of the bottom of the impressions, with some irregular angular notches towards its circumference, indicating them to have been made by a limb shod with a hard substance terminating in a somewhat obtuse point with angular processes from its base. This character of the impressions is irreconcileable with their having been formed by the convex sole of the foot of a Chelonian or by the more flattened foot of a Batrachian or Saurian reptile, or by the hoofed or padded foot of any mammal.

4. *Protichnites multinotatus.* Pl. XII. (¼ nat. size.)

Casts of impressions along an extent of 4½ feet, forming part of a series which was traced for an extent of 10 feet uninterruptedly, exhibit a strong deviation of the intermediate continuous groove from the mid-line between the two lateral series of impressions. The breadth of this track from the outer border of the outer impressions nowhere exceeds 3½ inches. The impressions are subcircular with smooth, rounded, ill-defined borders, of varying depth, but most of them faint and shallow. Commencing at the end of the series, where they are least distinct, the intermediate groove inclines to the left and soon gets upon the innermost of the impressions along the left side. At about halfway from the other end it becomes deeper, obliterates many of the prints on that side, and has been impressed so strongly as to force up a ridge of the sand upon its left side. Some faint

impressions of the outer prints may be seen on this ridge. The impressions of the right side opposite the deeper part of the ridge are unusually deep, and are more numerous and closer together than in the shallower parts of the tracks. In no part of the series are the impressions so distinct and well-defined as to allow a recognition of the groups of threes repeating each other; but in a few parts, as they approach the deep excentric groove, the small innermost pits may be observed. There are few places where two contiguous pits are divided by an interspace equal to their own breadth. Although many of the foot-prints on the same side are in pairs, more or less oblique, groups of three occur not unfrequently. Nothing like claws or digital divisions can be discerned where the impressions are deepest. The intermediate groove becomes shallow and gains the mid-space in the last two feet of the present series. Where the impression is deepest the tracks bend slightly in a different direction from the preceding part, making about an angle of 162°. This deviation of the middle impression would seem to indicate that it had been formed by some appendage which continued to incline to the left after the body had begun to bend to the right side, and the greater depth of the impression where the bend is greatest would show that there had been an increased exertion on the part of the animal at the time of making that bend.

5. *Protichnites lineatus*. Pl. XIII. (½ nat. size), and Pl. VIII. A. 3.

In a continuous track of the median impression, traceable along an extent of 13 feet, this impression preserves in some parts for an extent of between 2 and 3 feet a considerable and equable depth; it is also accompanied by a remarkable modification of the lateral impressions, which are rather represented by continuous grooves than by a succession of pits, although these are sufficiently evident in many parts of the lateral grooves, forming partial depressions in the grooves. Along an extent of 13 inches, where the deep median impression is equidistant from the two narrow and shallow impressions on each side, the outermost of these impressions is deepest on the left side, and the innermost is deepest on the right: a little further on the lateral grooves become broken up into a series of shallow foot-prints and then again become continuous in shallow grooves. After an uninterrupted course of 5 feet from one end of this series of impressions, the middle groove, after bending slightly to the right, terminates in a point, the impressing part appearing there to have been raised obliquely above the sand; but the impression recommences to the left and a little behind this point and somewhat more obtusely, and, again becoming shallower, it seems to have been partially reimpressed to the right of this, and then to have continued uninterruptedly, a little varied in its depth, for some feet further.

None of the impressions in this extent of tracks are sharply defined, the borders both of the grooves and pits being much rounded off, as if they had been partially effaced, either as having been made under water, or by water having passed over them soon after they were made. They give the idea of the animal having been partly supported by water whilst making them, so as to have occasionally

dragged its lateral appendages along, and thereby to have made a continuous groove with faint impressions, interrupted where the feet have been applied to the sand in the usual successive way.

The breadth between the outer margins of the outermost tracks is 5 inches 6 lines; between the inner border of the innermost tracks 3 inches 10 lines; the breadth of the median track is 10 lines. For a short distance there is a shallow longitudinal depression on the left border of the median track, and here and there are faint indications of small impressions inside of the innermost of the lateral tracks. The name indicative of this series of tracks is one of convenience only, and is not to be regarded as the sign of a species recognized as actually distinct from the differently-marked and better-defined impressions of the same size and breadth.

6. *Protichnites alternans.* Pl. XIV. (¼ nat. size), and Pl. VIII. A. 7.

In a series of impressions in which the middle groove is represented by a succession of interrupted shallow longitudinal channels, with unimpressed or slightly marked intervals of nearly their own extent, the lateral impressions are deep, small, and more or less of an angular character. In some parts there appears only a single impression, as at *a* on the left side, 1 *L*; an inch in advance of this there will be a pair, *b*, *b'*, placed rather obliquely, the innermost much larger than the outer one. One inch and a half in advance of this is a third more widely parted pair, *c*, *c'*, also placed obliquely, the inner impression being smaller than the outer one. Then at the same distance follows a triplet, *d*, *d'*, *d''*, or a pair, *d*, *d'*, of nearly equal size, and on the same transverse line, but wider apart than the rest. About 2 inches in advance of this is a pair, *e*, *e*, which are nearer together, and then comes either a very large single impression or one composed of a confluent pair, *f*. The outer impressions of the series describe a curve, with the convexity turned outwards, but the opposite impressions of the series are not symmetrical; for where the impressions are widest apart on the left side, those of the right, as in 1 *R*, are nearest together, or, being confluent, appear single; and where the right pair of impressions are widest apart, those of the left side are nearest together. The innermost impressions of both lateral series preserve best their regular distance from the middle tracks. The outer impressions differ most in this respect, and consequently describe an undulating line, but so that when the convexity is turned from the middle line on the left side it is turned to the middle line on the right, and *vice versâ*. Some of the innermost impressions are elongated transversely and become gradually shallow outwards, as if the foot impressing them had been moved from within outwards.

These impressions indicate a waddling gait, or an alternate oblique movement from side to side of the animal, with an alternate raising and depressing of the part of the animal which has left the middle impression. Here and there groups of three impressions are interposed between the impressions in pairs. The shape of the impressions indicates them to have been made by hard, pointed, subangular extremities.

The average breadth of the track from the outermost side of the outer impressions is 5 inches. From the median track to the outermost of the outer impressions is 3 inches, and to the innermost of the same pair of impressions 1 inch 3 lines. The longitudinal extent of one of the curves which includes five sets of prints is 7 inches. The interrupted impressions of the median track show a slight deviation from the straight line.

The modifications presented by this series of impressions equally militate against their having been left by a vertebrate animal, but differ so much from those already described as to clearly indicate a distinct genus of many-limbed animal.

There are four series of impressions on a great extent of ripple-marked sandstones, in one of which the median track has cut through the ripple-marks along an undulating curved line of nearly equal and considerable depth, not showing the alternate rise and fall which is seen in so many of the other sets of impressions. The margins of this median track are rounded off, and it is more rounded at the bottom. The lateral tracks are large, shallow, and faint, as if they had been partially obliterated by the action of water; yet the prints can be still distinctly traced, indicating a total and regular breadth of 6 inches across the whole of the impressions.

Along another extent of ripple-marked slab, a narrower median impression cuts through the ripple-risings for an extent of 7 feet in nearly a straight line. Here also the lateral impressions are faintly indicated, their borders being rounded off and as it were expanded, showing a total breadth of 5 inches, across the tracks. As the sand appears to have been of a dense siliceous character, the ripple-marks could have only been ploughed through to the depth shown by these impressions, by a pretty considerable momentum, either of velocity or of weight, occasioned by the moving animal.

Along a third extent of ripple-marked surface the median impressing part of the moving body has left only a narrow and shallow impression upon the summits of the successive sand-waves, the direction of the animal being shown by that in which the sand had been pushed into the intervening valleys of the ripples.

With these varied and well-marked evidences of the number, form, grouping, and arrangement of the foot-prints impressed upon the Potsdam sandstone, in the more clearly impressed specimens, now submitted, both in the original sandstones and in good plaster-casts, to our inspection, we may readily discern a general correspondence with them, of those comparatively more confused and obscurely marked impressions (Pl. XIV. A.), the casts of which were first brought over by Mr. Logan during the preceding year. The foot-print occasionally occurring on the inner side of the pairs of prints, may now be recognized as answering to that marked *c* in Pl. X., which forms the innermost impression of the regularly recurring group of 3, viz. *c*, *c'*, *c''*. It is not, as I at first supposed, the result of the fore-leg being applied to the ground a second time, on the inner side of the first step, during a temporary stop in the animal's progress.

The recognition of the real nature of this superadded print also leads to the recognition of the succession of the prints in progressive series of three groups, two of which seem to consist of a pair of prints, as in the *Protichnites 7-notatus**. That peculiarity could not, I believe, have been recognized, or satisfactorily confided in, without the aid and light of the analogies furnished by the more numerous and extensive, clearer and better-marked, impressions which have now been submitted to us by their zealous and indefatigable discoverer and collector. I need scarcely say, therefore, that although the foot-prints of a Tortoise are those to which the original series of the Potsdam sandstone impressions bore the closest resemblance, I have now the conviction that they were not made by a Chelonian reptile, nor by any vertebrated animal.

The impressions selected for Plates IX. and X. clearly demonstrate that the animal, progressing in an undulating course, made at each action of its locomotive members, answering to the single step of the biped, and the double step of the quadruped, not fewer than, in *Protichnites 7-notatus*, fourteen impressions, seven on the right and seven on the left; and in *Protichnites 8-notatus* sixteen impressions, eight on the right and eight on the left; these seven and eight impressions respectively being arranged in three groups; viz. in *Protichnites 7-notatus*, 3, 2, and 2; in *Protichnites 8-notatus*, 3, 2, and 3; the groups being reimpressed, in successive series, so similarly and so regularly as to admit of no doubt that they were made by repeated applications of the same impressing instruments, capable of being moved so far in advance, as to clear the previous impressions and make a series of new ones at the same distance from them, as the sets of impressions in the series are from each other. What then was the nature of these instruments? To this three replies may be given, or hypotheses suggested:—they were made, either, 1st, as in the case of quadrupedal impressions, each by its own limb, which would give seven and eight pairs of limbs to the two species respectively; or, 2ndly, certain pairs of the limbs were bifurcate, as in some insects and crustaceans, another pair or other pairs being trifurcate at their extremities; and each group of impressions was made by a single so-subdivided limb, in which case we have evidence of a remarkably broad and short hexapod creature; or, 3rdly, three pairs of limbs were bifurcate, and the supplementary pits were made by small superadded limbs, as in some crustaceans; or, 4thly, a single broad fin-like member, divided at its impressing border into seven or into eight obtuse points, so arranged as to leave the definite pattern described, must have made the series of three groups, by successive applications to the sand.

The latter hypothesis appears to me to be the least probable; first, as being most remote from any known analogy, and secondly, because there are occasional varieties in the groups of foot-prints which would hardly accord with impressions left by one definitely subdivided instrument or member. Thus in the group of impressions marked 1 *L*,

* This will be seen, on a comparison of the original and entire series of foot-prints, more satisfactorily than in the small portion figured in Plate XIV. A.

in Pl. IX., the outer impression, c', is single, but in the preceding set it is divided: whilst the impressions a, a', are confluent in that set, and are separate in 1 *L*. The same variety occurs in the outer pair, c', c'', in *Protichnites* 8-*notatus*.

Yet, with respect to the hypothesis that each impression was made by its own independent limb, I confess to much difficulty in conceiving how seven or eight pairs of jointed limbs could be aggregated in so short a space of the sides of one animal. So that I incline to adopt as the most probable hypothesis, that the creatures which have left these tracks and impressions on the most ancient of known sea-shores belonged to an articulate and probably crustaceous genus, either with three pairs of limbs employed in locomotion, and severally divided to accord with the number of prints in each of the three groups, or bifurcated merely, the supplementary and usually smaller impressions being made by a small and simple fourth, or fourth and fifth pair of extremities.

The *Limulus*, which has the small anterior pair of limbs near the middle line, and the next four lateral pairs of limbs, bifurcate at the free extremity, the last pair of lateral limbs with four lamelliform appendages, and a long and slender hard tail, comes the nearest to my idea of the kind of animal which has left the impressions on the Potsdam sandstone*.

The shape of the pits, so clearly shown in the ice-rubbed slabs, impressed by *Protichnites* 8-*notatus*, accords best with the hard, subobtuse, and subangular terminations of a crustaceous ambulatory limb, such as may be seen in the blunted legs of a large *Palinurus* or *Birgus*; and it is evident that the animal of the Potsdam sandstone moved directly forwards after the manner of the *Macrura* and *Xiphosura*, and not sideways, like the Brachyurous Crustaceans.

The appearances in the slab impressed by the *Protichnites multinotatus* favour the view of the median track having been formed by a caudal appendage, rather than by a prominent part of the under surface of the trunk.

What further conjectures the contemplation and comparison of the several series of foot-prints from the Potsdam sandstone have originated in my mind, I do not deem it very helpful to their full understanding at present to record.

The imagination is baffled in the attempt to realize the extent of time past since the period when the creatures were in being that moved upon the sandy shores of that most ancient Silurian sea; and we know that, with the exception of the microscopic forms of life, all the actual species of animals came into being at a period geologically very recent in comparison with the Silurian epoch.

The deviations from the living exemplars of animal types usually become greater as we descend into the depths of time past; of this the Plesiosaur and Ichthyosaur are instances in the reptilian class, and the *Pterichthys*, *Coccosteus*, and *Cephalaspis* in that of fishes. If the Vertebrate type has undergone such inconceivable modifications

* [This paragraph was added whilst the paper was being prepared for the press. May 13, 1852.—R.O.]

Jos. Dinkel, del. et lith.

during the Secondary and Devonian periods, what may not have been the modifications of the Articulate type during a period probably more remote from the Secondary period than this is from the present time! In all probability no living form of animal bears such a resemblance to that which the Potsdam foot-prints indicate, as to afford an exact illustration of the shape and number of the instruments and of the mode of locomotion of the Silurian *Protichnites*.

These most precious evidences of animal life, locomotive on land, of the oldest known sedimentary and unmetamorphosed deposits on this planet, have been, I am well aware, far too inadequately described in the paper which I have had the honour to submit to the Society. They offer characters which require more time for their due scrutiny and greater acumen and powers of interpretation than have hitherto been bestowed upon them. The symbols themselves are distinct enough. Old Nature speaks as plainly as she can do by them; and if we do not fully thereby read her meaning, the fault is in our powers of interpretation. In the present attempt I can, however, truly aver, that I have bestowed upon it all the leisure at my command, and have applied my best abilities in the endeavour to fulfil my obligations to their discoverer, and to satisfy the generally expressed wishes of the Society.

April 7, 1852.

Lieut. Julius Roberts, R.M.A., and the Hon. D. F. Fortescue were elected Fellows.

The following communications were read:—

1. *On some of the* Effects *of the* Holmfirth Flood. By Joseph Prestwich, Jun., Esq., F.G.S.

The broad tract of hilly country, which stretches north and south on the borders of Lancashire and Yorkshire, rises, in some places between Manchester and Huddersfield, to the height of nearly 2000 feet. The central ridge is here composed of the Millstone Grit Series, the elevated surfaces of which form extensive barren moors, and from which, owing to their lithological character and the large fall of rain, the surface-drainage is very considerable. On its eastern slope, the water is carried off by numerous small streams, falling into the various tributaries of the Humber. Their usual course is through narrow and picturesque valleys, which penetrate deep into the hills; amongst them is that of the Holme, which commences in the central range of hills, winds for nine miles east and north, and then joins the valley of the Colne at Huddersfield: it is well-wooded, and the scenery is generally bold and fine. At a short distance from the top of the valley, the Holme is joined by the Digley streamlet; the latter, however, being apparently the main stream, and draining, according to

Capt. Moody, about 1920 acres of surface. It at first flows through a narrow and uncultivated ravine, which, three miles above the small town of Holmfirth, opens out into a narrow valley. This valley has always been subject to occasional floods, arising, however, from natural causes: one of the most disastrous occurred in 1777. The bottom of the valley shows beneath the turf an accumulation, several feet thick, of local gravel and rolled fragments of rocks. In some places debris of this description overlies 2 to 3 feet of imperfect peaty matter, which again appears to repose on similar detrital accumulations. This drift, however, is much water-worn, and does not seem to contain any masses of rock at all approaching to the dimensions of those transported by the late flood.

The following outline map shows the course of the stream and the situation of the principal places referred to.

Fig. 1.—*Course of the River Holme and Digley Stream.*

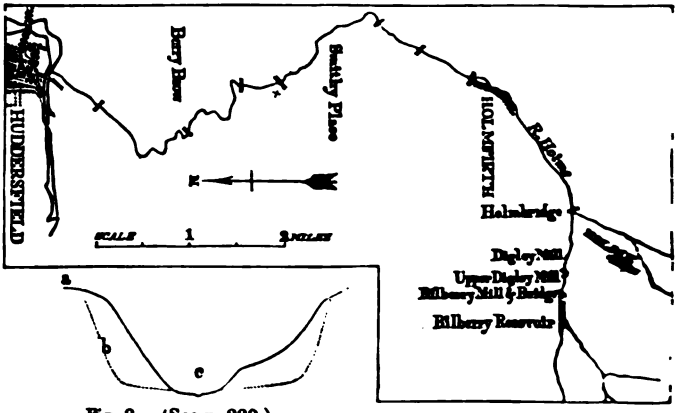


Fig. 2.—(See p. 229.)

Between 1840 and 1844, an embankment 96 feet high (but which afterwards subsided to 87 feet), about 480 feet wide at base, 16 feet at top, and 340 feet in length, was thrown across the valley of the Digley, three miles above Holmfirth. By this means an artificial lake, known as the Bilberry Reservoir, about a quarter of a mile long, 300 to 400 feet broad, with a surface of rather more than 11 acres, and in the centre from 70 to 80 feet deep, was formed. It was calculated that, when full, this reservoir held 86,248,000 gallons of water. The dam was constructed of a wall of clay-puddle, 8 feet wide at top, and 16 feet at bottom, with a mass of the debris of the valley, consisting of earth and stones, on either side. The inner slope was paved with squared stone, and had a base 3 to 1; the outer slope, a base of 2 to 1.

On the night of the 4th of February last, the giving way of this embankment caused the sad catastrophe, of which the papers have so

recently given an account. The object of the present communication is merely to notice briefly a few facts bearing upon the geological question, and having reference to the transporting power of water.

The portion of the embankment destroyed extends to its full depth, and forms a gap about 140 feet in width at top, and 25 feet at bottom. The weight of the materials thus swept away, and scattered in gradually decreasing quantity for a distance of half a mile, cannot be much less than 40,000 to 50,000 tons. A large proportion, however, is deposited within the first 300 feet. At this point a stone-built mill, two storeys high, was situated: all that portion of it in the way of the flood-stream was at once swept down, and the site covered with 6 to 10 feet of debris. As far as this the valley is very narrow, and the action of the water on the slopes on its side tore up the surface to a depth of 10 to 20 feet (forming a small cliff-like bank where it had been a slope previously, see fig. 2), and carrying away large masses of rock to considerable distances. It is to be observed, however, that the first rush of the waters out of the reservoir excavated a circular pool in the old water-channel at the foot of the embankment. The rock in this pass has a dip of about 5° nearly in a direction down the valley, and consists of a pebbly quartzose conglomerate, of a character easily recognised.

Just below the mill the valley opens out from a breadth of 30 to 50 yards to that of 100 to 200 yards, and the force of the flood became necessarily much diminished; still the meadows extending from this point to Digley are almost entirely covered to a depth of from 1 to 2 feet, with masses of rock mixed with sand and gravel, derived from the embankment and the sides of the pass above-mentioned. The bulk of the debris scattered over the valley consists of angular fragments of rock not exceeding 1 or 2 feet in diameter; but amongst them a few large rough blocks stand out in prominent relief. As the portion of the outcrop of the rock exposed to the action of the torrent was not large, the sides of the valley being much covered with debris, these larger masses are not numerous. There are four which particularly attract attention. One of these, a block measuring 7 feet in extreme length by 5 feet in breadth, and 2½ feet in depth, and weighing probably from 5 to 6 tons, has been transported a distance of about half a mile, and now lies in the valley near Digley Mill. There is near it another mass of about the same size. A third block, rather nearer the reservoir, measures 12 feet by 6½, and 2 feet deep, and may weigh 7 or 8 tons. The most remarkable block, however, lies in the middle of the valley, near Upper Digley Mill, and at a distance of a third of a mile from the parent rock; it is 22 feet long, 6 feet broad, and 3½ feet thick, and probably weighs about 20 tons.

Although the greater part of this portion of the valley is covered with debris, there are places where its surface has been torn up to the depth of from 4 to 5 feet. This also occasionally occurs in other places lower down the valley, but generally the centre of the valley has been covered with debris, which the denudation of the banks in the narrower passes has furnished. In the middle of the open part of the valley, above Upper Digley Mill, an old oak-tree still stands,

notwithstanding the many hard blows it received, and of which the marks remain on the bark. In fact, all down the valley, trees, chiefly ash, have stood, where buildings have given way. It is also to be observed that, although many have been uprooted, few have been broken down. These results probably are due to the branches having been in most cases above the reach of the flood, and to the absence of foliage.

At Digley Mill, the valley contracts to a width generally not much more than sufficient for the passage of the stream, and continues so for nearly a third of a mile. The mill, which was a substantial stone-building, four storeys high, stood at the entrance of this pass, and at the other end of it, but rather on one side, was Bank End Mill. The flood swept the first mill entirely away, with the exception of the tall massive square chimney, which remains almost uninjured; whilst the last-named mill is cut in two, the remaining half presenting a clean open section. The ruins of these mills and the debris derived from the denudation of the sloping banks of the pass are thickly scattered for a distance of half a mile along the valley where it again expands above Holme Bridge. The church of this village stands in the valley, which is here 700 to 800 feet wide. One of the stone posts placed at the entrance of the church-yard was broken in two, and one part, 6½ feet long by 1½ foot square, I found at a distance of 150 yards lower down the valley. All the slabs on the tombs were removed to distances of from 50 to 200 yards; and this occurred where the waters having spread out had lost much of their force. All down this part of the valley, as far as Holmfirth, a distance of 2½ miles from Digley Mill, are found pieces of a peculiar dark-grey micaceous flagstone, 6 to 12 inches in length and 2 to 3 inches thick, both in a rough state and in squared blocks used for building. This bed crops out close by the above-named mill, and was used in its construction. The rocks in this second pass consist of grits and sandstones.

At Hinchliffe Mill, between Holme Bridge and Holmfirth, the valley is again contracted, and at this point a row of six small stone houses was entirely swept away. The height to which the water rose above its ordinary level was here 26 feet. Below this the valley again becomes wider, and presents for a distance of 1½ mile a surface covered with wreck, but to a less extent than higher up. The walls and fences are levelled, and some houses swept away; but the five or six mills have sustained comparatively little damage. The fields are covered with gravel and fragments of rock, but none of the fragments are of a very large size; a few only may be 1 to 2 tons in weight. In Holmfirth, at which we next arrive, the bridges were dismantled, and several buildings levelled to the ground or partly destroyed; but most of the debris remains *in situ*. In the church-yard, which stands rather above the river, some large flagstones were however removed to a distance of from 50 to 100 yards down the stream.

Below this spot the effects of the flood are less marked. Stone walls have been thrown down, some small buildings and bridges de-

stroyed, and no inconsiderable injury otherwise done; whilst the fields, that were overflowed, are covered in places by sand and gravel, which, however, gradually decreases in quantity and becomes finer. The last strong action of the flood is exhibited at Berry Brow, within two miles of Huddersfield. The stone walls of the churchyard, which is situated in the valley, have, on the two sides transverse to the valley, been thrown down, and the stones carried a distance of 100 to 150 feet. Near Huddersfield the waters rose 6 to 8 feet, but, beyond covering some of the meadows with sand, they did no material damage.

The large iron boilers of various mills destroyed in the course of the stream were carried to considerable distances by the flood. That at Digley Mill, which weighed 10 to 12 tons, was found more than a mile lower down the valley. At Smithey's Place, two miles below Holmfirth, an equally large boiler was swept away, and now lies in the bed of the river at Berry Brow.

Notwithstanding the force and violence of the torrent, fishes, with which the reservoir was well stocked, were transported a long way comparatively uninjured; many were picked up around Holmfirth in a state perfectly fit for use. I could find no shells or fragments of shells in the transported gravel or sand; neither did I observe any in the bed of the reservoir.

The fragments of rock show but little or no water-wear. They are chipped, much broken, and angular.

Of the slope of the valley I cannot speak. Between the Reservoir and Holmfirth, judging from the number of mills, the descent must be considerable. The passage of the flood-waters down to Holmfirth is said to have been effected in a quarter of an hour, and in an hour the waters had retired. The main fall of the flood was, however, almost as rapid as the rise. In some of the descriptions of this catastrophe, it is said that the debris of the embankment was carried down the valley to a distance of three miles, but this, owing to the structure of the valley, appears to me to be questionable; for, as before mentioned, the valley consists of open flats and narrow passes, and it is in these latter that the force of the flood has been especially felt. This is particularly apparent in that part of the valley which is only 20 to 30 yards wide, just below Digley Mill. The diagram, fig. 2, p. 226, shows generally the form of the excavation effected at the base of these passes: *c* marks the position and usual highest level of the stream; *a* represents the sloping surface, to a height of 10 to 20 feet above the stream, as it existed before the flood; *b* indicates by a dotted line the surface as it now exists after the flood. In these parts of their course the waters rose from 20 to 30 feet. Field-walls, houses, mills, and bridges, in these narrower places, were swept away with irresistible force, and many hundred tons of debris scattered over the valley.

But it seems to me that the debris has in almost every case been deposited, as might be expected, in the more open space succeeding each pass; and there the trail of debris gradually diminishes. At the passes, the waters, being again pent up, have torn up fresh materials

and transported them to the next open space. This is repeated a gradually decreasing force nearly all the way to Huddersfield.

It would be very desirable, while the effects of the Holmfirth flood are still recent, that exact measurements should be made of the width of the valley in its different parts, of the fall of the ground from the reservoir to the junction of the Holme with the Colne, of the height to which the water rose in various parts of the flood-stream, of the time taken for the water to rise and run off, &c., so that the velocity and power of the flood might be determined, and its results more accurately recorded. For if such are the remarkable effects of a temporary flood caused by a body of water comparatively so small, and along a valley where its power could not be maintained, we may form some conception of the enormous power which a more continuous flood, with more sustained action, would possess.

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2. *On the* Salt-range *of the* Punjaub. By Dr. A. Fleming.

[Communicated by Sir R. I. Murchison.]

[The publication of this paper is deferred.]

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3. *On the* Geology *of the* Neighbourhood *of* Kotah, Deccan. By Dr. Thomas L. Bell.

[Communicated by Colonel Sykes, F.G.S.]

The village of Kotah* is situated on a plain, on the left bank of the Pranheetah River, twelve miles above its junction with the Godavery, in latitude 18° 51′ N., and longitude 80° 2′ E.

This is the locality selected by the late Dr. Walker for the experiment of boring for coal, and from whence the specimens of fossil Fish (*Lepidotus Deccanensis*) were obtained that were figured and described in Quart. Journ. Geol. Soc. vol. vii. p. 272, Pl. XV. The "Station," where the bore was made, is situated on the bank of the river, about half a mile to the N.N.W. of the village.

To the westward the country (after crossing the river) is slightly undulating, as far as the town of Chinnoor, distant twenty miles; to the east the plain is bounded by an abrupt ridge of hills, distant five miles, which also, in consequence of their north-west and south-east direction, bound the plain to the north; on the south the country is open and flat.

On examining the surface, proceeding from Chinnoor towards Kotah, which lies nearly due east, the road is observed to pass over sandstone for four miles; which, about half a mile from the river Godavery, ceases, and changes to the "black regar" or "cotton

* The town of Kotah, on the Chumbul River, is situated about 450 geographical miles to the N.N.W.

soil* ;" this continues for about three miles and disappears as the road leaves the river, the sandstone again becoming visible, which is continued without interruption until we approach the Pranheetah at Annawarrum, distant one mile from it, where the "black regar" alluvium is again entered upon, and ends by forming the nearly perpendicular right bank of the river. The bed of the river measures 666 yards in breadth, with a bottom of fine white quartzose sand; the breadth of stream varies with the season, at present (June 17) it is narrower than at any other period of the year, and measures only 50 yards, with an average depth of 3 feet. Pursuing this superficial examination in the same line, the "black regar" is found to form the left bank, which is 43 feet in height, and then to pass easterly for nearly a mile; when it is gradually lost, its place being supplied by sand, pebbles, and quartzose conglomerate, the debris of the adjacent hills.

The hill which limits the plain to the east is one of the chain extending from Budrachellum; it has a N.W. and S.E. direction, and is 478 feet high above the level of the plain; its top is flat and covered with fragments of quartz-conglomerate (with a ferruginous cement) and iron-ore of various degrees of richness, from the yellowish brown spheroidal masses of clay-iron-stone, containing 35 per cent. of iron, to the red oxide, containing upwards of 70 per cent. The sides and base are likewise covered with the same.

This hill is composed of unstratified red sandstone, which at places becomes ferruginous, the oxide of iron forming layers from 2 to 4 inches thick; where this occurs the rock is less susceptible of atmospheric influence, and is not worn to the same extent as the surface generally, and the frequent projecting of these indurated portions gives it the appearance of being intersected by a number of septa.

Commencing from the most northerly point to which my observations have extended (Chicala, at a distance of twelve miles from Kotah), and proceeding southerly by the left bank of the river, three ridges of hills present themselves, of the same lithological characters as the one already described. These ridges are separated from each other by plains of the "black regar" alluvium. They have a N.W. and S.E. direction, are flat at the top, and terminate their northerly course at the river in escarpments of various heights. On approaching the "Station," and 200 yards from it, we come upon another sandstone-rock of a very different character, inasmuch as we find distinct marks of stratification and no septa of iron-ore. The rock is 36 feet high, and ascends perpendicularly from the water (which is here 14 feet deep); its strike is E.N.E. with a dip of 10° to the N.N.W.; its surface is bare only to a small extent, being for the most part covered with alluvium of "black regar," which is level with its highest point. The strata of this rock are made up of a number of thin layers arranged diagonally, separated from each other by coloured lines; these thin layers are composed of round grains of white quartz: between the strata is found a layer of conglomerate of quartz-pebbles. A few yards lower down the river, the outcropping of laminated sandstone, alternating with clay, is observed, with a similar strike and dip as the rock above; between these outcroppings

* A black alluvial earth, supposed to result from the decomposition of trap.

and the position of the bore-hole the surface is covered with a tough black mud. Proceeding south of the "Station," and a hundred yards from the bore-hole, is a confused heap of argillaceous limestone, extending down the bank of the river for 150 yards; the layers of this rock vary in thickness from the one-eighth of an inch to a foot, and are frequently separated from each other by seams of fibrous carbonate of lime; the thickest masses of this rock (weathered) exhibit crack-casts. Two miles lower down the river the sandstone is again visible, presenting the same stratified character as the rock situated 200 yards north of the "Station." The sandstone in this direction extends to Bagartepett, fifty miles on the road to Warungul, but is not stratified.

At the "Station" the boring carried on in search for coal exhibited the following results. The alluvium is 59 feet deep at the bank of the river; but it gradually diminishes in depth, and is altogether lost a mile from the river. Beneath this is a layer of blue clay, 1 foot thick. This is succeeded by a bed of argillaceous limestone: this is seen to outcrop in the bed of a nullah about a mile from the river in a S.W. direction; it is 9 feet 1 inch in thickness, and is occasionally fibrous. Under this is a very thin layer of bituminous shale *, which burns with a yellow flame, emitting a strong odour, and leaving a large residue of white ashes: the thickness of this bed is about three-quarters of an inch. It is superimposed upon a second stratum of limestone, 1 foot thick. Below this we have another layer of shale, 4 inches deep; followed by a layer of impure limestone and blue clay-rock, 8 inches thick, and a bed of bituminous shale 2 feet 1 inch. Then a recurrence of impure limestone, 1 foot 9 inches, resting upon sandstone and blue clay 8¾ inches in depth; these cover another layer of bituminous shale, 1 foot 1 inch thick, which is separated from another layer, 1 foot 3½ inches thick, by 1 inch of fibrous carbonate of lime. Limestone, 5 feet 3½ inches thick, was next cut through, and found to rest upon black sandy clay, 3 feet in thickness, 6 inches of which were pierced previous to suspending the work. So that we have the following deposits succeeding each other from above downwards:—

	ft.	inch.
Alluvium of "black regar" ("Cotton soil")	15	6
Blue clay	1	0
Argillaceous limestone	9	1
Bituminous shale	0	0¾
Argillaceous limestone	1	0
Bituminous shale	0	4
Fibrous carbonate of lime, impure limestone, and blue clay-rock.	0	8
Bituminous shale	2	1
Impure limestone	1	9
Laminated sandstone, blue clay, and shale	8	0¾
Bituminous shale	1	6
Fibrous carbonate of lime	0	1
Bituminous shale	1	3½
Impure limestone	5	3½
Black clay containing sand	3	6
	43	11½

* One specimen of black shale forwarded by Dr. Bell, and marked as belonging to this seam, bears fish-remains.

There appears to be no decided evidence of the existence of a coal-deposit at this spot,—the fossils being so very scarce. The vegetable impressions on the shale are too obscure for determination, and it is to be regretted that the fossils are so few and imperfect. There is only one spot from whence they can be obtained, and almost every stone had been examined before my arrival. Such, however, as were collected accompany this memoir*.

A waterworn fragment of rock, accompanying this communication, but not referred to in Dr. Bell's list of specimens, presented evidence of its containing Crocodilian remains. These have been carefully exposed by the chisel, under Col. Sykes's superintendence, and the specimen has been examined by Prof. Bell and Prof. Owen, the latter of whom has kindly furnished the accompanying note.

Note on the CROCODILIAN REMAINS *accompanying* Dr. T. L. BELL'S *Paper on* KOTAH. By Prof. OWEN, F.R.S., G.S.

THE Crocodilian fossil consists of a mass of dermal scutes, with a femur and some fragments of other bones, firmly cemented together by the matrix. The scutes are for the most part quadrate,—some square, others oblong; they have numerous well-defined and rather small hemispherical pits upon their outer surface, which is flat and without any carinal elevation. In this respect they differ from the dermal scutes of the existing Gavial, in which the pits are relatively larger, more frequently confluent, and the middle of the pitted surface is in most of the scutes raised into a keel.

The characters of the scutes, as well as the length and slenderness of the femur, in the fossil, agree more with those of the *Teleosaurus* and Amphicœlian Crocodiles than with the existing Gavials.

APRIL 21, 1852.

Charles Twamley, Esq., Adam Murray, Esq., and M. W. P. Scott, Esq., were elected Fellows.

The following communications were read :—

1. NOTICE *of the* OCCURRENCE *of an* EARTHQUAKE SHOCK *at* BRISTOL. By Fort-Major THOMAS AUSTIN, F.G.S.

[In a Letter to the President.]

As some particulars relating to the shock of an earthquake which occurred on Saturday the 3rd of April in this district may not be

* The specimens of shale here referred to accompany the series of specimens illustrative of the "Section" and of the rocks in the neighbourhood of Kotah. They contain fragmentary remains of the *Lepidotus Deccanensis*, and amongst them are fragments exhibiting parts of the head and tail of that fish. Unfortunately, however, the indications are too obscure for the purposes of illustration.

wholly uninteresting to the Fellows of the Geological Society, I do not hesitate to submit to your notice such facts in connexion with the subject as I have been enabled to collect from unquestionable sources of information.

The area principally affected comprises that portion of country extending from the Mendip Hills to Bristol, and the village of Henbury in Gloucestershire to the north, and probably on to the Severn; and from the Mendips to the Bristol Channel on the west.

The geological features of this district consist of old red sandstone, carboniferous limestone, millstone grit, coal-measures, dolomitic conglomerate, new red sandstone, lias, and oolite, with alluvial patches of some extent.

The principal line of disturbance appears to have been nearly north and south, running through the southern edge of the Mendips, the city of Wells, Cheddar, Pensford, and Dundry, in Somersetshire; Bristol, Westbury upon Trym, and Henbury in Gloucestershire. The chief focus of oscillation was at Cheddar, where the hill is said to have waved to and fro during several seconds; and in the alluvial flat or marsh below Cheddar, some houses had the plaster of the ceilings cracked, while in other houses the clocks struck, bells rang, &c.

At Dundry, an elevated ridge of inferior oolite, about five miles south of Bristol, the shock was sufficiently strong to slam doors, and to rattle the glass and china on the shelves, and even, in some instances, to cause apprehension that the chimneys would fall.

In Bristol and its more immediate vicinity, namely Clifton, Cotham, and Kingsdown, the shock was of still less intensity, but still sufficient to shake the houses and alarm the inhabitants. Some of the persons who experienced the shock describe it as an oscillatory motion of a few seconds' duration, while others represent it as resembling the sensation that would be felt if a heavy body fell to the ground, and by the collision produced a momentary vibration. Others experienced an unusual sensation not easily described. The time at which the shock was felt was about a quarter before six o'clock A.M., on the 3rd of April.

Some slight effects are said to have been perceptible at thirty miles distance from the localities enumerated, but this I have not been enabled to authenticate, though in all probability such may have been the fact.

No serious damage has occurred, but considerable alarm was created by the unexpected shaking of houses, &c. The period of oscillation did not exceed ten or twelve seconds, and the movement is represented as being accompanied by a low rumbling sound.

Two shocks are reported as having taken place on Saturday, April 3rd, the first at about three o'clock A.M., and which lasted only two seconds; but the second, which occurred at a quarter before six o'clock A.M., was of longer duration and more decided character.

2. *On the* STRUCTURE *of the* STRATA *between the* LONDON CLAY *and the* CHALK *in the* LONDON *and* HAMPSHIRE TERTIARY SYSTEMS. By JOSEPH PRESTWICH, Jun., Esq., F.G.S.

Part III.*—THE THANET SANDS.

[Plates XV. XVI.]

(Part II. is deferred until a later period for reasons assigned in the subjoined note.)

THE first part of this paper, containing a description of that portion of the Lower Tertiaries immediately under the London clay, and which I termed the "*Basement Bed of the London Clay*," was read before the Society in January 1850†. On that occasion my object was to show, that over the whole of the south of England tertiary area, a stratum forming a distinct and constant geological horizon clearly separated the London clay from the group of strata beneath it. The variable and interesting set of deposits between the Chalk and the London clay, including the "Basement Bed" of the latter, form the group hitherto called "the Plastic Clay Formation," which has been described "as composed of an indefinite number of sand, clay, and pebble beds, *irregularly alternating*," and as being "members of one great series of nearly contemporaneous deposits," and essentially of fresh and brackish water origin. A careful examination of these strata has led me to believe, on the contrary, that a regular and definite order of superposition does exist, and that, instead of one series of alternating and intercalated strata, the conditions of structure and changes in the fauna show that there are five well-marked and distinct groups. Three, however, of these groups are apparently synchronous. Therefore the number of consecutive and separate divisions of the Lower Tertiaries may be reduced to three‡.

The term "Plastic Clay Formation" was originally given to this series in conformity with the divisions introduced into the French tertiaries by Cuvier and Brongniart, and was deemed applicable in consequence of the prevalence of variegated plastic clays at many

* The difficulty of obtaining, in the very variable strata of the "Lower Tertiaries," a series of sections that would, to my mind, satisfactorily establish their division into certain well-marked and persistent groups, has caused a longer delay than I could have wished in bringing this inquiry to a conclusion; and even now I find it advisable to describe the lowest member of the series before the central one, that should in natural order have followed next, the better to detach out of the series this latter more complex group, the description of which I must postpone to a future period. [J. P., Jun.]

† Quart. Journ. Geol. Soc. vol. vi. p. 252.

‡ It is true that certain characters and fossils pervade the whole series, and it may be thought unnecessary to establish divisions on features not more distinctive than those which guide us in these papers; but if not standing out in the strong relief indicating more important geological changes, they are, though small in degree, definite in form, and exhibit the more delicate shadings, stamped as it were by the diurnal occurrences of the time. They may be less impressive than the greater changes, but, as they are equally a part of the progress of the period, and depict the more gradual and lesser alterations in the configuration of the surface and in the distribution of life, they are full of interest and indispensable in filling up those details of the scene, which are so necessary to enable us to trace accurately each successive step in the history of the time.

places around London, and, again, more especially near Poole in Dorsetshire. But in the London district these clays are restricted to the western portion of the tertiary area, and occur but in one division of the series; whilst the Poole clays belong, not to the beds beneath the "London Clay," but form part of the "Bagshot Sands" above it. It is to be observed also, that these subordinate clays which give the name to this formation are the unfossiliferous portion of the series, and consequently they present only a mineral designation, whilst the palæontological type has been taken from the local and subordinate fluvio-marine group of Woolwich, Bromley, and adjacent districts, which, owing to its more favourable exhibition and rich store of organic remains, has attracted a larger share of attention than its relative development would warrant, and its characters have come to be considered the ruling, instead of the subordinate, although important, feature of the "Plastic Clay Formation." For out of nearly 3000 square miles over which the "lower tertiaries" are spread, these fluviatile and estuarine beds occupy really an area of only about 200 miles, nor is their vertical development relatively more important. In fact, so far from the more fluviatile conditions prevailing in the lower tertiaries, this series exhibits, on the contrary, throughout a great part of its range, proofs of a distinctly marine origin, whilst in another part the absence of fossils renders the question of origin uncertain. With regard also to their mineral structure, the conjoint use of the terms "London Clay Formation" and "Plastic Clay Formation" is apt to convey a wrong idea, inasmuch as they might be supposed to be two argillaceous deposits, or at least in some measure related in lithological characters, whereas they are, as is well known, totally dissimilar, the one formation being strictly argillaceous, and the other mainly arenaceous but with subordinate clays and conglomerates.

For these reasons therefore it seems desirable to change the name of this part of the Tertiary series, or at all events to restrict the present one to that portion of the series in which the plastic clays predominate; but still this name indicates a physical character so essentially a part of the ordinary properties of clays, that even in this more limited division their strongly marked *mottled* appearance would afford a less general and better designation. I therefore propose for the present merely to call the series between the London clay and the Chalk "The Lower London Tertiaries," and to subdivide them into the following groups in descending order:—

The Lower London Tertiaries.

1. *The Basement Bed of the London Clay.*
2*. *The Woolwich and the Mottled Clays, Sands, and Pebble Beds.*
3. *The Thanet Sands.*

* The order of subdivision of this part of the series will be given in the next and concluding part of this Paper.

With reference to the French tertiaries, M. d'Archiac has discontinued the use of the term "Formation d'Argile plastique," and named the series of strata beneath Calcaire Grossier, the "Sables inférieurs," subdividing them into six groups. In his extremely valuable 'Histoire des Progrès de la Géologie de 1834 à 1845' (note, p. 598), he observes, "Quelques géologues, trop préoccupés du rôle que joue l'argile plastique dont on trouve des amas plus ou moins étendus, mais

The sands which in Kent immediately overlie the chalk are here formed into a separate division, as I believe them to be entirely of marine origin, and distinct from the sands incumbent on the chalk at Hertford, Reading, Newbury, and elsewhere westward of London, but with which these Kent sands have been hitherto considered synchronous. If such were the case, then certainly the mottled plastic clays and light-coloured sands lying between the chalk and the London clay at Reading might be regarded as the equivalent of the whole group of strata reposing upon the chalk at Woolwich and Upnor; but it can, I think, be proved that the Reading and Hertford beds are higher in the series than the Kentish sands, and that it is from the gradual thinning-out of the latter, as they range westward, and not by actual synchronous deposition, that this mottled clay group reposes immediately upon the chalk in Berkshire, and occupies therefore relatively to that formation the same position as the thick mass of lower sands in Kent *.

The grounds for this opinion will probably be better understood from the description of the several groups rather than by a prior enumeration of abstract reasons. As before mentioned, I purpose commencing in this instance, as more convenient for the general argument, with the lowest beds, viz.—

"The Thanet Sands†."

I have used this term in consequence of these sands being best exhibited, and marked by organic remains, in part of the Isle of Thanet

ordinairement discontinus, vers la base et vers le haut de ce groupe, ont désigné celui-ci sous le nom de *groupe de l'argile plastique*; mais cette expression, assez juste lorsqu'on ne considère que les environs de Paris, devient au contraire tout à fait fausse lorsqu'on embrasse la totalité du bassin. On ne tarde pas à reconnaitre en effet que l'argile plastique proprement dite n'est qu'un accident de quelques mètres d'épaisseur subordonné à la partie inférieure d'une masse sablonneuse qui en a 80 et même davantage." These observations will apply to a certain extent to the English series; but the beds of mottled clay are in this country far more largely developed and hold a more important place in the Lower Eocene strata than M. d'Archiac describes them to occupy in France.

* Such is the difficulty of obtaining clear sections between the west of Kent and Berkshire, that even now it would not be safe to pronounce as a certainty that the whole of the Lower Tertiaries of the former county were of more recent origin than the Thanet Sands. It is possible that a small portion of the lowest beds may be synchronous with the latter. This, however, would only modify the divisions here proposed, and would not affect their general correctness.

† The only accounts we have of this lowermost bed are short abstracts of papers by Mr. Morris, Proc. Geol. Soc. vol. ii. p. 595, "On the Coast section from Ramsgate to Pegwell Bay;" and again at p. 450, "On the Strata usually termed Plastic Clay," wherein he describes the Woolwich and Upnor beds, and gives their relation to the Bognor and Herne Bay strata. In the same volume both Dr. Mitchell (p. 7) and Mr. Richardson (pp. 78 and 222) give some account of the cliffs at the Reculvers and Herne Bay, but these descriptions are very general. Brief notices of these sands, as forming part of the Plastic Clay series, occur also in Phillips and Conybeare's 'Geology of England' (pp. 37–51), and in papers by Mr. Webster (Trans. Geol. Soc. vol. ii. p. 196), by Dr. Buckland (Trans. Geol. Soc. vol. iv. p. 284), and by the Rev. H. M. De la Condamine (Quart. Journ. Geol. Soc. vol. vi. p. 440).

and in the immediately adjacent districts. It is these beds which form the cliffs at Pegwell Bay near Ramsgate (see section No. 1, Pl. XV.). They range inland from this point to Minster, but, although distinctly overlying the chalk, their position relatively to the other members of the "Lower Tertiaries" is not seen, as no beds higher in the series occur in this district. They are also well developed on the west bank of the Stour at the old Roman station of Richborough, and again on the side of the road in descending from Woodnesborough church towards Sandwich. The actual section at the former place, together with its relation to the strata at the latter place, and to the outcrop of the chalk, is shown in section No. 2, Pl. XV.

The Thanet Sands extend over nearly the whole of the district included between Sandwich, Canterbury, and the Reculvers, but are frequently overlaid by the middle division of the lower tertiaries, as in the section at Richborough. The higher beds of the lower tertiaries are here also wanting. The relation, however, of the lower divisions to the whole series can be studied in unbroken sequence in the cliffs between the Reculvers and Herne Bay, where the several members of the "Lower London Tertiaries" pass beneath the "London Clay" (see section No. 3, Pl. XV.). Further, not only is the co-relation of the several groups well exhibited in these districts, but each division has its distinct lithological character and fauna, and they are all under similar marine conditions, whereas, as these beds range westward, the frequent absence of fossils and the close similarity, in many cases, of lithological characters often render it difficult to determine the lines of separation of the different groups, except where the middle division contains subordinate fluviatile beds. In fact, in assuming that these Thanet Sands of the Reculvers and Richborough are the same as those which underlie the more fluviatile beds of the central group at Upnor and Woolwich (see sections 4 and 5, Pl. XV.), and repose immediately upon the chalk throughout Kent, Essex, and part of Surrey,—that they are distinct from the sands which alternate with the mottled clays incumbent on the chalk in West Surrey, Hertfordshire, Buckinghamshire, and Berkshire, and that the latter form a separate group,—it must be observed that neither mineral characters nor organic remains alone suffice to determine the question; for the proofs depend upon general structure and superposition, upon unity in the general design, and upon certain constant characters and conditions.

The following sections which I have given elsewhere*, and for the use of which I am indebted to Mr. Van Voorst, will serve to illustrate the relative position and importance of the several divisions of the "Lower Tertiaries" in their range from east to west.

These sections are on a vertical scale of 50 feet to 1 inch.

* "A Geological Inquiry respecting the Water-bearing Strata of the country around London," 1851. 8vo. John Van Voorst, London.

Fig. 1.—*Section of the Cliff a mile and a half east of Herne Bay.*

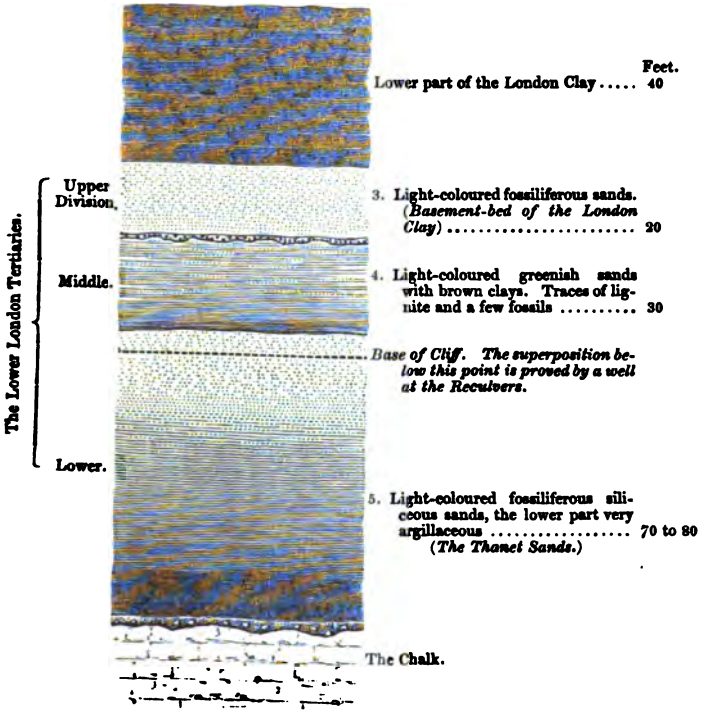

Feet.
Lower part of the London Clay 40
The Lower London Tertiaries.
Upper Division.
3. Light-coloured fossiliferous sands. (*Basement-bed of the London Clay*) 20
Middle.
4. Light-coloured greenish sands with brown clays. Traces of lignite and a few fossils 30
Base of Cliff. The superposition below this point is proved by a well at the Reculvers.
Lower.
5. Light-coloured fossiliferous siliceous sands, the lower part very argillaceous ..... 70 to 80
(*The Thanet Sands.*)
The Chalk.

Fig. 2.—*General section of the strata beneath London.*

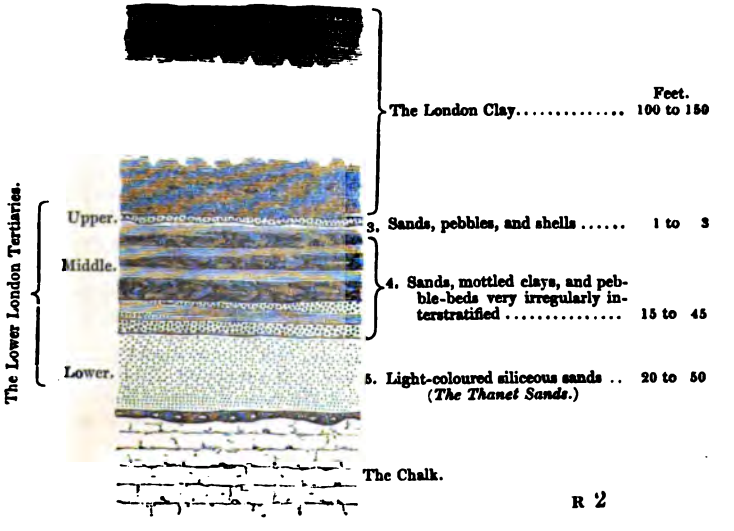
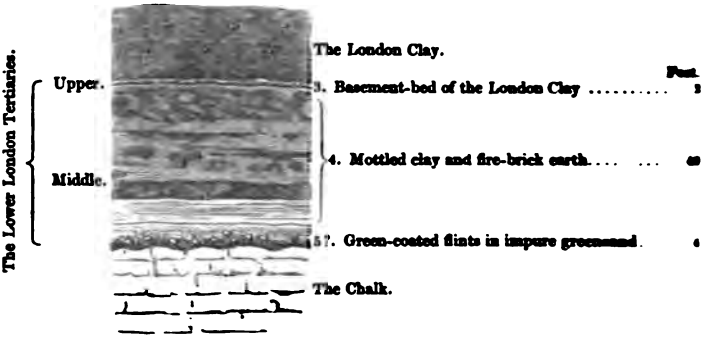

Feet.
The London Clay..... 100 to 150
The Lower London Tertiaries.
Upper.
3. Sands, pebbles, and shells ..... 1 to 3
Middle.
4. Sands, mottled clays, and pebble-beds very irregularly interstratified ..... 15 to 45
Lower.
5. Light-coloured siliceous sands .. 20 to 50
(*The Thanet Sands.*)
The Chalk.

Fig. 3.—*Section at the Brick-field, west of Hedgerley, six miles north of Windsor.*



1. *Range and General Physical Characters.*

From the north-east of Kent, the Thanet Sands range past Canterbury, Faversham, Sittingbourne, to Chatham, occupying the lower grounds sloping down towards the Swale and the Medway, and occasionally capping the tops of the chalk hills for a short distance inland. Crossing the Medway, they form a broader zone by Upnor and Cobham, thence in detached outliers by Gravesend, Swanscombe, and Dartford. Here they stretch further south, spreading over a tract of country extending between the valleys of the Darent and the Cray, and thence by Farnborough to Addington and Croydon in one direction, and to Erith, Woolwich, and Deptford in the other. Throughout these districts these sands are with few exceptions very fertile, and their usually well-wooded surface * contrasts strongly with the more open chalk tracts. They form extensive hop grounds, and a large proportion of the well-known fruit orchards of North Kent are situated on this deposit†. Dipping under the London clay at Deptford and Lewisham, these sands pass beneath London, and become available in another important way, forming the large water reservoir to numerous artesian wells, both in London and in the districts immediately north and south of it‡.

At the Reculvers, the Thanet Sands appear to be about 70 to 80 feet thick, though only 25 feet of them are exposed in the cliff section; but a well, which was sunk at the village, reached the chalk after passing through a continuation of these sands for a further depth of

* Taken in conjunction with the upper divisions of the Lower Tertiaries.

† In the north-east of Kent these Thanet sands, with a slight covering of drift loam, form some of the most valuable arable land of the county.

‡ In London, owing to the large drain upon this source, the water no longer rises to the surface; but at a distance of four or five miles on either side of the Thames, as at Tooting, Garrett, Clapton, and Waltham Abbey, it still continues to overflow, although with rather diminished power (see work before referred to, p. 238, note).

about 50 to 60 feet. In some parts of the neighbourhood of Canterbury they cannot be much less than 80 to 90 feet thick. They then apparently maintain a tolerably uniform thickness of from 60 to 70 feet, as far as Chatham, Upnor (Sect. No. 4, Pl. XV.), and Gravesend. At Bexley Heath they have been ascertained to vary in thickness from 45 to 55 feet, and at Woolwich I find that they are 60 feet thick. Beneath London their thickness averages from 30 to 40 feet. They then become more rapidly thinner as they trend underground further westward, being only 20 feet thick at Wandsworth, 17 feet at Isleworth, 7 feet at Twickenham, and 3 feet at Chobham, beyond which they thin out, although I believe that originally they probably had a range westward co-extensive in some measure with the green-coated flints overlying the chalk. Along their south line of outcrop westward of London, they are exposed at Croydon and Carshalton, and disappear, I think, somewhere about Ewell or Epsom*, but the sections are too few and imperfect to determine this point. To the north of London the Thanet Sands do not range so far as Hertford, for there, and also at Northaw, as I shall afterwards show, the sands and conglomerates which repose immediately upon the chalk belong to the middle division of the Lower Tertiaries. (See figs. 1, 2, & 3.)

In North Essex the zone of outcrop of these sands usually occurs on the slope of hills, and they therefore form a very narrow belt, which is further frequently so obscured by drift, that they do not constitute any marked feature in this district. Owing to this cause and the want of sections, their structure there remains uncertain †. Their thickness may be from 30 to 50 feet. In South Essex, however, they are well exhibited in the line of country between Purfleet, Grays, and East Tilbury; and are as fully and similarly developed there as in the opposite part of Kent.

[Besides the localities mentioned elsewhere in the text, the following are some other places at which sections of the *Thanet Sands* are exposed—Harbledown and Whitehall westward of Canterbury; around Boughton near Faversham; on the N.W. of Shottenden Hill, four miles S.E. from Faversham; and again in the lanes traversing Bysing Wood, one mile W. from Faversham; the hill between Key Street and Newington Street, near Sittingbourne; Ottersham Quay, near Rainham; and in the lane leading from Lower Rainham to Rainham, and that between Tweedale and Gillingham; road between Stroud and Gad's Hill, and west slope of Gad's Hill; lane leading from the high-road to Shorne Ridgeway, and also the one leading

* In the brick-field at Nonsuch Park, near Ewell, the "Mottled Clays" are well exhibited, and evidently descend very near to the chalk, but the section is imperfect. In the railway-cutting at Epsom I found the "Thanet Sands" reduced to a thickness of 14 feet. At Headley-on-the-Hill, the mottled clays with an underlying band of *Ostrea Bellovacina* repose immediately on the chalk, without the intervention of the Thanet sands. At Fetcham, a few miles west from Epsom, a bed of sand 25 to 30 feet thick overlies the chalk, but I believe it to belong to the "Mottled Clay" series, as it is underlaid by the bed of *Ostrea Bellovacina*.

† The country is so obscure on the borders of Herts and Essex, that I cannot well determine where the "Thanet Sands" end and are succeeded by the "Mottled Clay" group. This latter, however, is in full force at Ware, and again near Bishop Stortford, but its structure is here very variable, frequently passing into sands difficult, without better sections, to distinguish from the "Thanet Sands," which, judging from several small sections, probably commence somewhere near this latter point.

to Shorne, and from Gad's Hill to Higham; several lane cuttings between Cobham, Ifield, and Thong; south side of Windmill Hill, near Gravesend; especially the lane leading from Betsham to Stone, on the S.W. side of Swanscombe Wood, near Greenhithe; the lane leading from Darent to Darent Wood, just where it enters the wood, and the lane leading from Bexley to Baldwin's Park; lane leading up the hill N. of the Abbey Wood Station; the lanes and roads in the neighbourhood of North Cray, St. Paul's Cray, and Orpington; the lane just east of Kevingdown near St. Mary's Cray; pit on the Bromley road just below the windmill at Chiselhurst; lane sections and pits at Grays, Little Thurrock, Chadwell, and West Tilbury; pits at Charlton; others on the hill between Lewisham and New Cross; and pit in Coombe Lane, Croydon.]

2. *Lithological Character.*

The mineral structure of this deposit is very simple. It consists essentially of a base of fine light-coloured quartzose sand, mixed, in its lower beds more especially, with more or less argillaceous matter, but never passing into distinct clays. It also contains a small proportion of dark green grains*, which sometimes give to these beds, otherwise on the whole of a very light yellow or stone colour, an extremely slight ash-green tinge; but in the stratum, 2 to 6 feet thick, immediately lying upon the chalk, they so predominate as to form an impure argillaceous greyish greensand, very constant in its position and characters. Examined through a microscope, the grains of sand appear colourless and subangular, worn, but not rounded. In the upper part of this deposit they form a loose unadhering mass made up almost entirely of pure quartzose grains, but in descending, these bright transparent grains appear mixed with an opaque whitish argillaceous powder. The argillaceous matter is usually light-coloured, and does not therefore colour the sands, merely giving a certain amount of cohesion, so that when dry the beds are sometimes semi-indurated. In some places, however, the clay with which the sands are mixed is darker-coloured, as in the lower beds at Pegwell Bay† and Herne Bay. A peculiarity of these clayey sands is the very marked difference of colour which some of them exhibit when wet and dry—a difference greater than usual. In places, beds, which when wet are of a rather deep dark grey colour, not only become many shades lighter when dry, but actually seem to lose all colour, and turn so white as to resemble chalk at a distance. The top of this deposit is also occasionally coloured ochreous by the peroxide of iron, as at Richborough, Herne Bay, and at Boston Common near Plumstead. With these exceptions the general colour and appearance of the lower sands is remarkably uniform, hardly varying throughout Essex, and in Kent from Faversham to Greenwich. It rarely forms very distinct strata, excepting always its basement-bed, but exists as a thickly bedded mass of fine sand (in great part nearly white), except where, in the N.E. of Kent, it becomes, in its lower beds especially, darker and more argillaceous, and shows a well-defined stratification.

* It is, however, the middle group of the "Lower London Tertiaries" that is more particularly marked by the presence of green sands; they form one of its distinctive characters.

† It is this bed which probably helps to form the good anchorage-ground of the Downs, which are opposite to Pegwell Bay.

The upper part of these sands near London, and throughout the greater part of Kent, appears to be almost perfectly free from carbonate of lime, and in the middle and lower parts usually mere traces of it are present. A rough analysis of six specimens from various localities yielded only from 1 to 2 per cent. At Herne Bay and Pegwell Bay, however, carbonate of lime is present in greater abundance, so as to be readily detected by the ordinary tests. It forms, a few feet from the top of the deposit, at these places, a tabular bed of large, hard, flat, concretionary masses, effervescing strongly with dilute acid. At Wingham, near Canterbury, these beds form a considerable thickness of semi-indurated fossiliferous marls. As this division approaches London, the carbonate of lime almost entirely disappears*: owing to this cause, and the perfect permeability of the strata, even the carbonate of lime of the shells, of whose existence we have some evidence, has been entirely removed.

A distinctive feature of this division is, that it never contains layers or beds of those rounded black flint-pebbles so common in the overlying divisions, nor does it ever exhibit subordinate beds of those mottled clays which so well mark the middle division. A few rounded flint-pebbles, some few even as large as a cannon-ball, have been occasionally found in the mass of the lower sands, but they are usually dispersed singly, and are of very rare occurrence.

Mica is sparingly disseminated in the sands. At Pegwell Bay, however, it occurs in a thin band of sandstone, in quantity sufficient to divide it into fine laminæ. The peroxide of iron slightly tinges some of the beds, and forms occasionally small nodular sandy concretions and casts of the interior of the shells. It is sometimes present in the form of veins traversing the sands diagonally, and also in patches as stains in the sands, but it never forms solid masses or layers of ferruginous sandstone. With the exception of the calcareous sandstones of Pegwell Bay and the Reculvers, the Thanet Sands very rarely, if ever, contain blocks or layers of concretionary sandstone. At Erith, such masses of flat, tabular, very hard sandstone have, it is true, been found near the top of the pit†; and in the lane leading from Gad's Hill to Shorne Ridgeway, a block of this description was to be seen, apparently *in situ*, a short time since in a cutting through either the upper part of these sands or the lower part of the middle division. These sands may possibly have furnished some of the large masses of sandstone which so commonly occur in the drift on the edge of the chalk downs in Kent, but I believe that the bulk of them were derived from the next division of these Lower Tertiaries, and more especially from the "Basement-bed of the London Clay."

Small grains of selenite are, according to Mr. De la Condamine, frequently mixed in some abundance with these sands in the neighbourhood of Blackheath.

A very marked feature of the "Thanet Sands" is the constant occurrence at the very base of the deposit, and immediately reposing on

* At Faversham even the few fossils which are preserved are almost all in a silicified condition, and only traces of carbonate of lime are present.

† It is uncertain, however, whether these do not belong to the middle division.

the chalk, of a layer of flints of all sizes, just as they occur in the underlying chalk, from which in fact they appear to have removed comparatively without wear or fracture; for they are almost as perfect as the undisturbed flints, but present this difference, that instead of their usual white or black coating, these flints are almost invariably of a deep bright olive-green colour externally; the white outer coating, which is often very thick, seems removed (as though by an acid), and the flint then stained green. So strong is the colour, although it forms a mere film, that flints removed by denudation from this bed, subjected to great wear and many changes, and imbedded in fresh beds, whether of the Tertiaries or the Drift, can always be recognized by the peculiar green colour which they invariably retain. The colour in fact seems to be not a mere stain, but an actual alteration in the structure of the flint, arising apparently from its having entered into a chemical combination with the iron of the mud or silt in which they became imbedded, forming in consequence a true silicate of iron. There is frequently a thick inner brown stain of the peroxide of iron, but as in the silicate the iron is usually in the state of the protoxide, it would almost appear as though the flints had been imbedded at the sea-bottom in a ferruginous mud, and that then some cause, productive of an action on the silica, and a decomposition or deoxidization of the mineral containing the iron, acted simultaneously on the two, and brought them, in presence, into a state in which they would readily combine. To this however I merely direct attention; it is a subject which needs a special inquiry. If it should prove to be, as I anticipate from the few experiments I have made, a true chemical combination, it will be a curious fact, for almost all the minerals in which the silicate of iron is a main ingredient, as the chlorites, amphiboles, pyroxenes, &c., belong to rocks of igneous or metamorphic origin. Its formation by moist means seems to be the exceptional case; but should the view here suggested be correct, it will show that there may be cases in which sedimentary beds of greensand may have derived their characters from changes subsequent to their deposition, as well as by the more usual direct disintegration of the unstratified and metamorphic rocks.

There is on the whole in the Thanet Sands a uniformity and breadth of character entirely wanting in the overlying division of the Lower Tertiaries, which deposit is on the contrary extremely variable in its structure, showing rapid changes within short distances and great variety of lithological composition. This well-maintained regularity in the one, whilst the accompanying overlying beds undergo at the same time considerable alteration, is in fact one of the features which serves to mark the two divisions, notwithstanding that the middle group, in its many phases, occasionally puts on characters so resembling the lower ones as to render it difficult to distinguish them apart. This fact will, however, be brought out more clearly in describing hereafter the next or middle division of the Lower Tertiaries.

For a more particular account of the lithological characters of this deposit at a few given places, see the descriptions of sections, p. 250, and Explanation of Plate, p. 261.

3. *Organic Remains.*—The fauna of this division of the Tertiary series is both limited in its species and confined in its range. In a few localities only are its fossils at all abundant, and they occur in patches and irregular layers, in which, although the number of individuals is sometimes great, the species are always few. Nevertheless they form a well-marked and distinct group, a large proportion of which is peculiar to this deposit. This scarcity of organic remains is in part attributable probably to the mineral character of the strata, for these being almost entirely composed of fine siliceous sands, with an admixture of clay and carbonate of lime only (apart from a few exceptional cases) in very small and variable proportions, they are generally very porous and permeable. It is these beds which, as before mentioned, constitute the main water-bearing strata beneath the London Clay. They everywhere admit of the passage of water, with which they are invariably charged when below a certain level. The consequence of this is, that the substance of the shells has been almost always removed, or, where it remains, it is generally in an extremely friable state. Where the sands are sufficiently argillaceous, the casts of the shells often remain; but where this is not the case, even traces of them are of very rare occurrence. Where, however, in addition to the clay, carbonate of lime is present in appreciable quantity, then the shells are preserved in considerable numbers, but they are generally very tender and difficult to remove.

By these observations I do not mean to imply that the "Thanet Sands" may have been originally equally fossiliferous in West as in East Kent, for it is probable that the causes which have favoured the preservation of the shells when dead, may also have tended to their development when living. That it is at the same time a true cause to a certain extent, is evident from the fact that in a few exceptional cases, which we shall hereafter mention, where the fossil has by chance been brought into a condition to be uninfluenced by the action of water, then a few isolated proofs of the existence of animal life, in areas otherwise barren, have been preserved.

At the south end of the section at Richborough, the fossils are numerous and perfect. A few yards further north, and still on the same level, the external casts only are found. Many of these are in a beautiful state of preservation, but are exceedingly soft and friable. At the other end of the section the impressions are scarce, and the shells still more so. At Pegwell Bay and Herne Bay the Thanet Sands happen to be more argillaceous and calcareous than usual, and there the shells are more numerous and more regularly distributed, whilst the irregular calcareous concretions and the few layers of semi-indurated marls have served in both places to preserve the organic remains. In the upper bed, however, of loose incoherent yellow sand at Herne Bay, the irregularity in the occurrence of the fossils is again observable. At their highest level, near the Reculvers, they are full of friable shells, which become scarcer, and finally disappear, although numerous impressions remain, as the bed trends westward and dips beneath the central beds of the Lower Tertiaries.

A peculiar condition of the fossils sometimes occurs at Rich-

borough and the Reculvers; in some of those cases where the shell has been removed, the animal matter has resisted decomposition and forms an earthy brown semi-elastic film covering the internal cast. In burning it gives off ammonia in abundance. Judging from the same test, animal matter is often traceable in the blackish green mud-like sediment in which the green-coated flints are imbedded.

On the side of the road on Woodnesborough Hill, about one furlong N.N.E. of the church, I found a few years ago fragments of numerous shells in the sands 30 to 40 feet above the chalk. In the lanes 1 and 1½ mile W. of Ash, leading down the south slope of the hill, along which the road from Sandwich to Canterbury passes, I have found casts of the *Cyprina Morrisii*; and again at Wingham, nearer to Canterbury, there is a considerable thickness of the Thanet Sands in a semi-indurated state and containing numerous impressions of shells. The road just out of the village, and leading to Preston Street, cuts through these beds, whilst on the top of the hill the sands of the central division of the Lower Tertiaries are largely quarried. In a field just below the cottages 1¼ mile 13° W. of N. from Wingham Church is a bank of the Thanet Sands full of casts of shells; and again on the sides of the lane leading up E. from the small valley halfway between Upper Hoath and Beaksbourne Street, and just two miles 22° S. of E. from Canterbury Cathedral, is an excellent section of the Thanet Sands in their semi-indurated condition and abounding in fossils, but all in a state of casts both internal and external. On the high-road about 1½ mile W. from Canterbury I have also found traces of casts of shells.

In all these places, the characteristic and by far the most abundant shell is the *Cyprina Morrisii*. The *Cucullæa crassatina*, one or two species of *Artemis* or *Cytherea* (including the *C. orbicularis* of Edwards), the *Thracia oblata*, *Pholadomya cuneata*, *Corbula longirostris*, a small *Leda*, and *Ampullaria subdepressa*, are far from uncommon. Other species are comparatively scarce.

A large number of the bivalve shells have been drilled by Zoophagous molluscs, but the proportion of shells belonging to this latter class preserved in these strata is very small.

Westward of this district the organic remains of the Thanet Sands become exceedingly rare. Some years since Mr. Crowe found the *Cucullæa crassatina*, and, I believe, a few other shells, but all in the state of siliceous casts, in the lower part of the Thanet Sands between Faversham and Boughton*, but the section no longer exists. I have carefully examined numerous sections between Faversham, Sittingbourne, Chatham, Upnor, and in many parts of the north-west of Kent, without being able to find more than slight indications of fossils, and even these indistinct traces are uncommon†. I have met

* It is said to have been in a field near the brook in Nash Park. If so, it could not have been many feet above the chalk.

† Since writing the above, I have found in a bank bordering the lane, one furlong due S. from Oakwell Farm, which is, by the Ordnance Map, exactly 2¼ miles due W. from Faversham Church, a seam full of shells in the state of semi-opaque siliceous casts. The *Cyprina*, *Cucullæa*, and a *Cytherea* are common. The silicification

such traces between Tweedale and Gillingham; and at the ballast-pits at Erith* the casts of bivalve shells are occasionally found. Mr. Morris states that the cast of the *Pholadomya* has been met with in the lower sands at Woolwich. Mr. Taylor confirms this fact, inasmuch as he has found impressions of shells in the sands at the large ballast-pit near the Charlton station, and amongst them an indisputable cast of a *Pholadomya*. In the various sections of these sands which I have examined in Essex, I have never been able to find any organic remains.

There are, however, some very curious oviform bodies occasionally met with in considerable abundance in the lower part of the Thanet Sands. I first noticed them in Pegwell Bay, and afterwards at Shottenden Hill; more recently I have found them in still greater quantities at Bexley†, and in a pit one mile nearly due W. from West Tilbury Church. They form short quill-like tubes, consisting of an aggregation of egg-shaped bodies about the size of cress-seed (see Pl. XVI. fig. 11). There is no organic structure visible, but this is apparently owing to the organic matter being removed and replaced by an infiltration of argillaceous matter from the surrounding matrix. Is it possible that these bodies may be the eggs of Gasteropodous Molluscs?

Throughout Kent the traces of vegetables in a very fragmentary state are not uncommon. They are generally mere small indistinct impressions in the soft sand, or sometimes equally indistinct fragments of carbonaceous matter, but they never occur in the connected form and to the extent which they do in the overlying group. At Grays and Woolwich long tubular fucoidal-looking casts are not uncommon; and east of Herne Bay the large flat tabular masses of calcareous sandstone are often covered with long vermiform impressions and casts, apparently of *Fuci* or of spongiform bodies.

In the determination of the species of Molluscs in the accompanying list, Mr. Edwards and Mr. Morris have been so good as to assist, and the latter to undertake the description of the new species. I give columns of the three principal fossiliferous localities, but, as before mentioned, there are other localities in which many of the species are found. To Mr. T. Rupert Jones I am indebted for an examination of several specimens of the Thanet Sands for Foraminifera. He found them only in a few specimens, and then but rarely‡. The chief locality where they occur is Pegwell Bay.

At Richborough small bones and scales of fishes occasionally occur, but I could not meet with any specimen sufficiently perfect to determine the species. Teeth of the *Lamna* are also found in several places.

is not very perfect, some portion of the shell being generally wanting. Very beautiful casts, in clear transparent quartz, of a very small *Corbula*, are, however, perfect in form and very abundant. Sponge *spicula* are also abundant.—*May* 1852.

* Mr. Morris informs me that teeth of the Shark have been found in the Thanet Sands at Erith. I have just found there a large *Cyprina*.—[July 1852.]

† In the lane leading towards Dartford Heath.

‡ Mr. Jones has also been enabled to add to my list a few Foraminifera and one Entomostracan, that he had previously collected from the Thanet Sands of Pegwell Bay.

Organic Remains of the Thanet Sands.

c Common. cc Very common. ccc Very abundant. r Rare. rr Very rare.		Richborough.	Pegwell Bay.	The Reculvers.	Highest vertical range in the English marine Tertiaries.
Univalves.					
Ampullaria subdepressa, *Morris* (*a.*)...	c	*	*	*	
Calyptræa trochiformis, *Lam.*?	rr	...	*	...	Barton Clay.
Chemnitzia or Eulima, a very small species	rr	...	*		
Dentalium nitens, *Sow.* (*a**.)	r	*	*	*	Barton Clay.
Fusus, one or two species	r	...	*	*	
Rostellaria or Aporrhais	rr	*			
Scalaria Bowerbankii, *Mor.* pl. 16. fig. 9 (*a*†.)	rr	...	...	*	
——, a smaller species (*b.*)	rr	*			
Trophon subnodosum, *Mor.* pl. 16. fig. 10.	rr	...	...	*	
Bivalves.					
Arca, one, or probably two, small species (*c.*)	r	*			
Astarte tenera, *Mor.* pl. 16. fig. 6 (*d.*)	r	*	...	*	Basement-bed L. Clay.
Cardium, large species	rr	...	*		
Corbula globosa, *Sow.*?	c	*	*	*	Barton Clay.
—— longirostris, *Desh.* (*e.*)	c	*	*	*	Brackleshaw Clay.
Crassatella	rr				
Cyprina Morrisii, *Sow.*	ccc	*	*	*	Basement-bed L. Clay.
——, a rather larger species (*f.*)	c	*	*	*	
Cytherea orbicularis, *Mor.* pl. 16. fig. 5.	c	...	*	*	
——, a rather smaller species (*g.*) ...	r	*	*	*	Basement-bed L. Clay.
——, a very small species	cc	*	*		
Cucullæa crassatina, *Lam.* (*h.*)	c	*	*	*	Mid. Div. L. L. Tert.
Glycimeris Rutupiensis, *Mor.* pl. 16. fig. 2.	r	...	...	*	Mid. Div. L. L. Tert.
Leda substriata, *Mor.* pl. 16. fig. 7. ...	c	*	*		
Lucina (*i.*)	r	...	*		
Modiola	r	...	*	*	
Nucula Bowerbankii, *Sow.*	c	*	*	...	London Clay.
—— fragilis, *Desh.* (*j.*)	c	...	*	*	
—— margaritacea, *Lam.*?	c	...	*	*	Barton Clay.
Ostrea, a very small species	r	*	*		
——, a large species	rr				
Panopæa granulata, *Mor.* pl. 16. fig. 3 (*k.*)	r	...	*	*	
Pecten Prestvichii, *Mor.* pl. 16. fig. 8.	rr	*	...	*	
Pholadomya cuneata, *Sow.*	c	...	*		
—— Koninckii, *Nyst* (?) (*l.*)	c	*	*	*	
Pinna	r	*	*		
Ringicula turgida	rr	...	...	...	Barton Clay.
Sanguinolaria Edvardsii, *Mor.* pl. 16. fig. 1.	c	...	*	*	
Saxicava compressa, *Edw. MSS.*? (*m.*)	rr	...	*		
Thracia oblata, *Sow.*	cc	*	*	*	London Clay.
Entomostraca.					
Cythereis, nov. sp.	rr	...	*		

c Common. cc Very common. ccc Very abundant.	r Rare. rr Very rare.	Richborough.	Pegwell Bay.	The Reculvers.	
Foraminifera.					
Nodosaria bacillum, *Defr.*	r	...	*	...	Occurs in the L. Clay.
Cristellaria platypleura, *Jones*	c	...	*		
—— Wetherellii, *Jones*	c	...	*	...	Occurs in the L. Clay.
Rosalina Mariæ, *Jones*	rr	...	*		
—— Beccarii ?, *Linn. sp.*	rr	...	*		
Polymorphina ampulla, *Jones*	rr	...	*		
——, sp.	rr	...	*		
Miscellanea.					
Scales and small bones of Fishes	rr	*	*	*	
Traces apparently of Crustaceans	rr	...	*		
Traces of carbonized plants and fragmentary vegetable impressions	cc	*	*	*	
Long tubular casts, probably fucoidal or spongiform	c	*	*	*	
Sponge spicula.					
Oviform bodies, filling tubular cavities.					

(*a.*) This was first referred to the *Natica labellata*, which is quoted by M. d'Archiac as occurring in his "Sables Inférieurs," but not in the lower stage of it. M. Melleville also gives it from his lowest division of these sands near Rheims.

(*a**.) The only species of *Dentalium* given by Nyst, from the "Système Landenien," is the *D. strangulatum*.

(*a*†.) This very much resembles a species brought by Sir Charles Lyell from the Lower Tertiary sands ("Système or Terrain Landenien" of Dumont) of Folx-les-Caves in Belgium, but the specimen is a cast, and not sufficiently perfect for positive identification.

(*b.*) The specimen is very imperfect, and may be the young of the preceding fine specimen, which is in the collection of Mr. Bowerbank. M. Nyst, on the authority of Galeotti, quotes the *Scalaria acuta* ?, Sow., which is a Barton species, from the "Terrain Landenien" of Folx-les-Caves.

(*c.*) One of these much resembles the *Arca depressa*, Sow., which occurs in the Woolwich clay beds.

(*d.*) M. Nyst figures a specimen from the "Terrain Landenien" of Folx-les-Caves, and names it *A. inæquilateralis*. It closely resembles the English species.

(*e.*) M. Melleville gives this species amongst the fossils of his lowest division of the "Sables Inférieurs."

(*f.*) It is doubtful whether this be not the species figured by M. Deshayes as the *C. scutellaria*, a species mentioned both by M. D'Archiac and M. Melleville as of not uncommon occurrence in the lowest division of their "Sables Inférieurs." The figure given by Nyst of a specimen from some of the much more recent Tertiaries of Belgium is probably not Deshayes's species.

(*g.*) One of these species may possibly prove to be the *Cytherea Bellovacina*, Desh., which Deshayes states to be common in parts of the "Sables Inférieurs" of the North of France. M. Melleville also gives it.

(*h.*) This is also a characteristic species of the "Sables Inférieurs" of the North of France. M. d'Archiac places it in his 3rd division (reckoning upwards from the chalk); M. Melleville in his lowest.

(*i.*) M. Nyst figures a specimen (*L. Galeottiana*) which a good deal resembles the smaller Pegwell Bay species. Amongst other deposits in which it is found, he mentions the "Terrain Landenien."

(*j.*) This occurs in the "Sables Inférieurs" of Beauvais.

(*k.*) The *Panopæa* occurs in the "Système Landenien" of Belgium, and in the "Sables Inférieurs" of France.

(*l.*) This is apparently the *P. Koninckii* of Nyst, who figures it as a characteristic

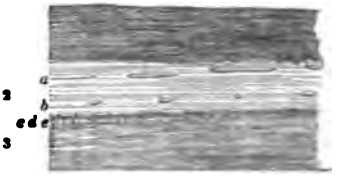
shell of the "Terrain Landenien." The *P. margaritacea* is also mentioned by Nyst as a fossil of the "Terrain Landenien," and by D'Archiac and Melleville as from the "Sables Inférieurs."

(*m.*) Resembles the *Saxicava Grignonensis* of Deshayes.

We have therefore in the Thanet Sands 39 species of Testacea, of which 24 are determined. Of these only 6 are common to the whole of the Eocene series, and 2 more range as high as the London Clay. Of the remaining 16 peculiar to the *Lower Tertiary strata*, 3 extend into the "Basement-bed" of the London Clay, and 2 to the level of the Woolwich group, whilst as many as 11, or nearly one half of the whole, are peculiar to the Thanet Sands. The distinction is not to be attributed to different conditions of the waters, for although at Woolwich this has necessarily operated by excluding the more marine species and introducing in their place others of fluviatile and æstuarine origin, still in, and adjoining, the Isle of Thanet, both the middle and upper divisions of the Lower London Tertiaries are marine, and consequently the conditions in this respect of the three groups are equal, and still the difference of fauna holds good.

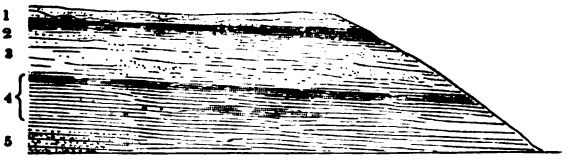
Annexed are the detailed sections of the two localities where the Thanet Sands are most fossiliferous (the Reculvers excepted). Their relation to the other parts of the Lower London Tertiaries is shown in sections 1, 2, & 3, Pl. XV.

Fig. 4.—*Section of part of the Cliff at Pegwell Bay, near Ramsgate.* (*s* in Section 1, Pl. XV.)



	Feet.
1. Drift of light-coloured brick-earth, with a thin irregular seam of gravel (angular and small round flints), mixed with broken fragments of the shells of the underlying beds, at its base	4–6
2. Light yellow slightly clayey sand with shells in layers and patches; "*a*," tabular masses of fissile micaceous calcareous sandstone, with few shells,—a very small *Corbula* often occurs in great abundance; "*b*," small calcareous concretions, in which the *Pholadomya Koninckii* is not uncommon; "*c*," large concretionary blocks, often very argillaceous; their lower surface frequently presents masses of shells, especially the *Cyprina Morrisii*. Traces of Plants occur both in "*b*" and "*c*."	16
3. Grey clayey sands, rather dark when wet, but lighter-coloured when dry (the upper part especially looking at a distance almost like chalk),—the lower part is more argillaceous and darker; "*d*," a seam of grey clay with shells in patches; "*e*," a thin layer of impure greensand full of very friable shells. Several shells, especially the *Pholadomya cuneata*, a *Nucula*, and the small *Cytherea*, together with frequent traces of plants, are dispersed in some abundance and in a good state of preservation throughout this bed, "3"	15

Fig. 5.—*Section of the Sand-pit by the side of the Railway at Richborough Castle, near Sandwich.*



		Feet.
	1. Light brownish-yellow clayey sand with a few very scarce and not determinable bivalve shells	3
Middle division of the Lower Tertiaries.	2. Very sandy light brownish-grey clay full of small, rough, twig-like fragments or pieces of iron sandstone, with cores of yellow sand, and having the appearance of vegetable origin,—contains a very few and very small black flint-pebbles	2½
	3. Very light and loose ash-green sand, rather fine,—in some places coarser, with one thin seam of shells (*Corbula*, *Glycimeris*, and *Cyprina*). The lower part contains an occasionally ochreous layer. A few small round flint-pebbles are dispersed throughout. The lower part of this stratum has taken up part of the underlying bed, and the line of separation is, therefore, not very sharply marked	8
The Thanet Sands.	4. Rather bright ochreous clayey sand, passing down into a light brownish yellow colour, in some parts with seams of sandy clay. Casts of shells are common in this bed, but more particularly in the lower and more argillaceous part of it	7
	5. Light yellow loamy sand with shells in irregular layers and patches on the left hand of section. They are very abundant—in some places in fragments, in other places whole and perfect, but extremely friable	4

Beyond this a bed of hard semi-indurated sand, 3 feet thick, with a few shells, rises. Argillaceous beds, not well exhibited, succeed.

The surface on the top of this section consists of about 1 foot of earth, with a few pebbles, chiefly the rounded ones. The hill rises at the back about 10 feet higher, but no section is exposed. Small round flint-pebbles are numerous on the surface of the hill.

4. *Conclusion.*

From the facts brought forward in the preceding pages, but which, with regard to the middle division of the Lower London Tertiaries, will be described more in full hereafter, it appears that while this latter group exhibits on the same horizon, a fauna at one place marine, at another æstuarine, and at last passing into one chiefly fluviatile, the Thanet Sands maintain within the same area a uniform marine character. In its range westward the fossils are certainly few, but still the occurrence of the *Pholadomya*, which is never found in the Woolwich clays and conglomerates, or in the sands interstratified with the mottled clays, but is, as before mentioned, met with in the sands beneath the shelly fluviatile beds at Woolwich and Charlton, affords an unmistakeable proof of the different conditions under which the two divisions were formed. Taking therefore these facts, in conjunction with the persistent lithological character of the lower

deposit, and the irregularity in this respect of the other group, we are, I think, justified in maintaining over the whole area the divisions which we have found more evident and marked further eastward, and in assigning to the lower one a distinct and separate place in the Eocene series.

Bearing upon this question is another point of physical structure, the details of which will be given at length in my next paper, but which I may briefly allude to here. It has been mentioned that the upper part of the Thanet Sands is usually light-coloured and very uniform in texture, whilst in many places the lowest bed of the overlying division consists of rounded black flint-pebbles imbedded in a coarse green sand. When their mineral characters are thus perfectly distinct, the worn and indented line of junction of the two groups is often very marked. Sometimes it seems as if the mud and pebbles of the upper bed had been driven and *splashed* into the soft upper surface of the underlying "Thanet Sands." All the phænomena point in the same direction, and, taken generally, go to prove a change of conditions between the two periods. In the one case we have a deposit, littoral probably, but distinctly marine, and in the other a variable accumulation of coeval marine, æstuarine, and fluviatile strata.

At the same time it is to be observed, that when, as frequently happens, neither division contains any fossils, if some of the other distinctive features are wanting, and the upper group becomes more arenaceous, lighter in colour, and the conglomerates more diffused, the separation of the two groups is sometimes extremely difficult, for they seem to pass one into the other and to form a series, the upper part of which is hardly distinguishable in general appearance from the lower *. It is only when the characters of one or the other become, as it were, more concentrated, that the separation is clearly marked.

There is an objection to these subdivisions which may at once strike those who have been accustomed to view the "Plastic Clay Formation" as a whole and as a series of recurring strata, arising from the occurrence at the base of the "Thanet Sands" of Woolwich and Upnor, as well as of the "Mottled Clays" of Reading and Newbury, of the layer of argillaceous greensand with the rough green-coated flints, reposing throughout the range of both divisions immediately upon the chalk, and presenting throughout very similar mineral characters. This common character has always been considered an argument in favour of the synchronism of the two groups. At the same time it did not escape observation that the *Ostrea Bellovacina* was never found in this bed in Kent, whereas it was common at Reading and Newbury; but as even elsewhere in the latter district the occurrence of this fossil was by no means a constant character, its absence altogether in the former district was naturally not con-

* Even at the Reculver Cliff, notwithstanding the occurrence of organic remains, this is particularly the case, owing apparently to the materials of the upper bed of the Thanet Sands, having become mixed up with the lower part of the overlying division.

sidered very material*. It seems to me, however, that the oysters are not part of the flint bed, but were deposited upon it—sometimes, where little sand intervened, in contact with, or even partly amongst, the flints—at other times, and which is more commonly the case, as a separate and distinct layer overlying the flints. I believe that this oyster bed belongs to the lowest part of the central division of the "Lower Tertiaries." It has already been observed that this part of that group often consists of coarse argillaceous green sands mixed with more or fewer round flint-pebbles; therefore when this stratum comes into contact with the one containing the green-coated flints, the similarity of the matrix in either case is such as to render it difficult to draw any line of demarcation between them. Now with the oysters are almost always associated small rounded flints, which do not occur with the green flints beneath the "Thanet Sands," and the two forms of the flints exhibit the results of physical causes so entirely distinct that they cannot possibly be the result of the same agency: the enormous wear necessary to produce so perfect a form as the ordinary round flint-pebble could never have left the great, massive, angular, green-coated flints as it were unscathed; nor could the powerful but transient action necessary to uproot these flints from the chalk have sufficed to wear down and give finish to the more perfectly rounded pebbles. These latter, after having been worn down elsewhere, must have been spread over the former at a subsequent period, and mingled with the *Ostrea Bellovacina* which was then living on the spot.

Still it is evident, from the peculiar and distinctive character of these large angular flints lying on the chalk throughout the tertiary area, that their accumulation is attributable to one and the same cause—that their uprooting and dispersion must have been contemporaneous over the whole district. After this they were, in the instance of the Kentish area, covered by a thick deposit of sands, which did not extend into the Berkshire area† (fig. 1 & 3, *supra*), or else they have been subsequently denuded throughout the latter district and this basement-bed alone left, and re-covered immediately by the lower beds of the upper series, into the composition of which coarse green sands so often largely enter, forming therefore with the green-coated flint-bed a consecutive mineral series, not distinguishable from one another when viewed as a local phænomenon‡. This thinning

* At the same time the *Ostrea Bellovacina* was known to occur at Woolwich, in the upper and middle beds; at Bromley in some intermediate beds; and at Northaw and Hertford in beds immediately upon the chalk and under a considerable thickness of sands—facts supposed to show the irregular dispersion of this shell throughout the whole series, as well as the irregular grouping and distribution of the strata.

† The green-coated flints extend into the Hampshire tertiary district. Therefore the sea of the earliest tertiary time may have extended over all this area, although the accumulation of strata was afterwards interrupted, or the Thanet Sands have been denuded.

‡ Since writing the above, I am however informed by Mr. Lunn that he has found, in the green-flint bed immediately over the chalk at Charlton, remains of shells, apparently oysters, but in too fragmentary a condition for exact determination; also that the workmen showed him a large and perfect specimen of an oyster which they said came from this bed. This, however, is an exceptional case,

out of the Thanet Sands westward of London, and the rise of the "Ostrea Bellovacina" bed of Reading from the surface of the Chalk to the zone of the Woolwich fluviatile series at London, are points which are not clearly exhibited in open sections, but which are better made out by the sections afforded by the wells to the westward of London.

Although the Thanet Sands are limited in their range westward to about the parallel of Windsor, yet with regard to their range eastward it is probable that they attain a more important development in the north of France and Belgium than in England. I have seen them in the neighbourhood of Calais, where they underlie the London clay, and from the description of M. Galeotti* and Omalius D'Halloy†, it is probable that the beds overlying the chalk at Tournay belong to this same age. The *Pholadomya*, *Panopæa*, *Astarte*, and *Cucullæa* are there found in beds of nearly the same mineral characters, but their associates are species which do not occur in England. There is, however, apparently some error in the lists of these shells. When the results of M. Dumont's admirable researches are better known, the comparison of these lower tertiaries will be readily made. He has already published a sketch of the co-relations of the Belgian with the French and English tertiaries‡, but as it is unaccompanied by sections and without lists of organic remains, I cannot judge of its accuracy. In his visit to this country last summer, he pointed out to me the many characters common to these Thanet sands and to his "Landenian System," which occupies the same position in the Belgian series §.

The recent visit of Sir Charles Lyell to Belgium will, I have no doubt, remove the uncertainty which we feel respecting the organic remains, and throw light on the relations of the English with the Belgian tertiaries,—a point of much interest, as these two series are evidently much more closely related than the English are with the French series.

The lower tertiary beds in France have been described by M. Elie

as I have never myself found any traces of shells in this bed in the numerous sections of it I have examined throughout Kent, nor can I hear of their having been observed by others. It is, however, quite possible that the *Ostrea Bellovacina*, or some other large species of oyster, may occur in the Thanet sands, as several species of shells are common to this and the overlying group. I have, in fact, recently found a fragment of a large oyster in the lower part of these sands, near Faversham, but it is evidently not the *O. Bellovacina*.

* Mém. de l'Acad. de Bruxelles, vol. xii. 1837, and also his separate work on the geology of Brabant.

† Coup d'œil sur la Géologie de la Belgique, 1842.

‡ Rapport sur les travaux de la Carte Géol. de la Belgique, 1839, in the Bull. de l'Acad. Roy. de Bruxelles, vol. vi. p. 11. *Ibid.* vol. xvi. 1849. "Sur la position géologique de l'Argile Rupelienne, et sur le synchronisme des Formations tertiaires de la Belgique, de l'Angleterre, et du Nord de la France," *Ibid.* vol. xviii. No. 8, 1851.

§ Since writing this paper I have visited the "Système Landenien," in the neighbourhood of Mons and Tournay, and perfectly agree with M. Dumont in considering it synchronous with the "Thanet sands." His determination of the order of superposition of the Belgian tertiaries seems as skilful as, there is every reason to believe, it is accurate. I had not, however, an opportunity of examining any but the lower divisions of the Tertiary series.—*May* 1852.

de Beaumont *. He particularly notices the chloritic sands in the north of France as constantly reposing upon the chalk and forming numerous detached outliers, and discusses their relations to the lignites of the Soissonnais and to the Calcaire grossier. M. D'Archiac has since distinguished these sands under the designation of the "Glauconie inférieure," constituting the sixth or lowest division of his "Sables inférieurs," which include all the beds between the Calcaire grossier and the Chalk †. It is with this group that the Thanet Sands appear to me to bear the closest resemblance, although there are some anomalies in the evidence afforded by organic remains. The only fossils quoted by M. D'Archiac from these sands are casts of the *Cyprina scutellaria*, a *Serpula*, a species of *Sponge*, bones of *Emydes* and of a small carnivore (*Palæocion primævus*, Blainv.); whereas amongst the shells which he mentions as characterizing his fourth division of the "Sables inférieurs" (Grès et Sables coquilliers) are the *Cucullæa crassatina* and *Corbula longirostris*, the former one of the most characteristic species of the Thanet sands. With them are associated the *Ostrea Bellovacina*, two species of *Venericardia*, *Nucula fragilis*, *Cyprina scutellaria*, &c. These two divisions are separated by the "Lignites and Argile plastique."

Some marine beds, far more fossiliferous than the above, have been described by M. Melleville ‡ and M. Hébert § in the departments of the Aisne and the Marne. M. Hébert considers that this deposit is synchronous with the sands of Bracheux and Abbecourt, and that they both underlie the lignites and repose immediately upon the chalk, except where the "Sables de Rilly" and the "Calcaire pisolitique" intervene. M. d'Archiac on the contrary is of opinion that these beds, equally with those of Bracheux, &c., are higher in the series, and above the "Lignites and Argile plastique ‖."

In this uncertainty, and pending a fuller description of the fossils of these lower marine tertiaries in France, it would be premature to conclude with which one or more of these beds the "Thanet Sands" are the exact equivalent, although I have no doubt of its including the "Glauconie inférieure" of the more northern parts of France, but where unfortunately this stratum is comparatively unfossiliferous ¶.

Neither the "Glauconie inférieure" nor the lower marine sands range to the south of the parallel of Paris.

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* "Sur l'Etendue du Système Tertiaire inférieur dans le Nord de la France," Mém. Soc. Géol. de France, vol. i. p. 107, 1833.

† Bull. Soc. Géol. de France, vol. vi. p. 240, 1835; *Ibid.* vol. x. p. 173, 1839; and Hist. des Progrès de la Géologie, vol. ii. p. 599, 1848.

‡ Bull. Soc. Géol. de France, vol. ix. p. 214, 1838. Ann. des Sciences Géol. vol. ii. p. 7, 1845.

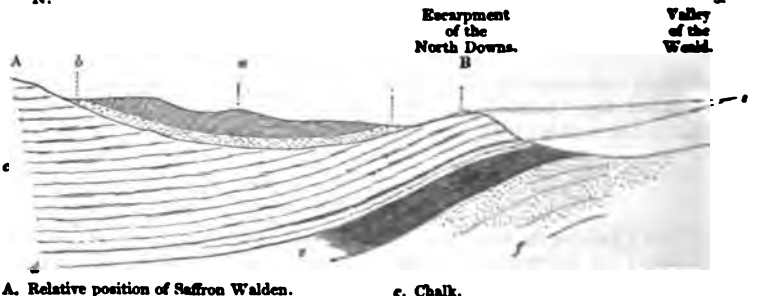
§ Bull. Soc. Géol., 2nd series, vol. v. p. 388, 1848; vol. vi. p. 695 *et seq.*, 1849; and vol. vii. p. 338, 1850.

‖ Hist. des Progrès de la Géol. vol. ii. p. 607.

¶ Several other local works may be consulted with advantage on this subject; amongst them are those of M. Buteux on the Department of the Somme, and M. Graves on the Department of the Oise.

General considerations respecting the distribution of land and water in the English Tertiary area at the commencement of the Eocene period.—In no part of the tertiary area of the south of England is there any indication of a passage either in mineral structure or in organic remains between the Chalk and the Tertiary series. With regard to the physical conditions, the change is most marked and abrupt. Extensive and deep wear of the chalk evidently took place before the commencement of the lowest Eocene deposits. In the neighbourhood of Calais, at St. Vallery-sur-Somme, Pegwell Bay, Upnor, Woolwich, Stortford, and thence to Reading, Newbury, Salisbury, Newhaven, and Alum Bay, the chalk invariably presents a worn though not very irregular surface, and is strewed over, as before mentioned, with those peculiar green-coated flints. This mass of flints, although generally not above 1 to 2 feet thick, in itself indicates a wide destruction of the chalk. But independently of this, another denudation had probably previously worn down a very large mass of the chalk along the southern boundary of the London tertiary area. In this direction all the upper beds, and a large portion of the middle beds of the chalk, have been removed; and it is probably owing to this cause that the chalk, which has been ascertained to be above 1000 feet thick at Saffron Walden, and is apparently about 800 to 900 feet thick at Luton and along its northern line of escarpment, becomes apparently gradually thinner as it ranges towards London, and eventually becomes reduced at the edge of the escarpment overlooking the Weald to a thickness not exceeding on the average 400 feet *. The following diagram (fig. 6), which gives the general representative section, independently of the exact conformation of the surface, from Saffron Walden to the chalk-escarpment above Godstone, exhibits the structure of the chalk here referred to:—

Fig. 6.—*Diagram to illustrate the thinning out of the Chalk in the direction of the axis of the Weald.*



A. Relative position of Saffron Walden.
B. Chalk escarpment above Godstone, surmounted with a patch of the Lower Tertiary beds.
a. London Clay.
b. Lower Tertiaries.
c. Chalk.
d. Upper Greensand.
e. Gault.
f. Lower Greensand and Wealden.
g. Point at which the present upper and under surfaces of the Chalk, if they were prolonged, would converge.

* At Bushey near Watford the chalk-marl was reached at a depth of less than 400 feet beneath the tertiaries, and at London the lower chalk without flints commences at about 250 feet below the surface of the chalk, which is here, as well

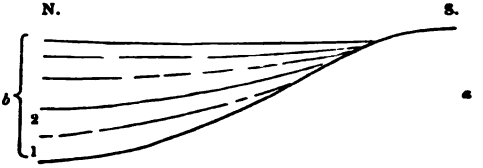
It therefore appears that the chalk was extensively denuded before, or at the commencement of, the deposition of the oldest tertiaries, and that this denudation was stronger towards the south than the north; consequently the chalk, to have been brought within the action of these denuding forces, must have had its surface more exposed in one direction than in the other, and have undergone, even at this early period, in order to have become so exposed, an elevation to the south of the tertiary area and about parallel with the escarpment of the North Downs. The phænomena in the Hampshire tertiary district seem to be very similar; although, from the complete denudation of the South Downs, tertiary outliers, like those on the North Downs, are wanting, still there are indications of the lower tertiary beds having spread over the chalk. It follows therefore that if the ratio of decrease in the thickness of the chalk were continued from Hertfordshire, then beneath the London tertiaries, and across the North Downs, to the Wealden area (before its denudation), it is probable that, before reaching the centre (*x*) of the latter district, the chalk had either thinned out altogether or else existed merely as a thin crust; and consequently that an elevation of the lower cretaceous and Wealden series, intermediate between the London and Hampshire tertiary districts, or in fact in the position of the present Weald, had already taken place before any of the tertiary beds were deposited.

It may be objected that the elevation of this central Wealden mass already existed before the chalk was deposited,—that it was a shoal in the old chalk sea,—and even that the cretaceous series formed originally but a thin covering over this part of the old sea-bed, and only attained their full development as the water became deeper towards the north. If this however were the case, there would be an overlapping in some part of the series, and we should further have the lower cretaceous beds (1 & 2, fig. 7) wrapping round this shoal with a thickness gradually increasing as we receded from it into deeper water, so that on the edge of the shoal itself the lower beds would be necessarily very thin or wanting, whilst we should have in the upper beds of the chalk near this centre (*a*) indications of a littoral zone.

But we find both the Gault and Upper Greensand on the whole as well developed in Kent and Sussex (*y*, fig. 8) as in Cambridgeshire and Bedfordshire (*x*). Nevertheless there is a change in the Lower Chalk —the Clunch of the latter counties is evidently a far thicker and more important rock than the Lower Chalk of the former counties. It is therefore not improbable that there was a slow and quiet movement of elevation in Kent, or of depression in Cambridgeshire, and whose commencement might date from changes that took place at the end

known, covered by 100 to 200 feet of tertiary strata. From Croydon and Epsom, towards Merstham and Dorking, there is evidence indicating that the chalk is probably not more than 400 to 500 feet thick, whilst on the summit of the North Downs overlooking Godstone, Reigate, and Dorking there are outliers of the *lower tertiary beds*, which reach to the very edge of the escarpment overlooking the *greensand district*; and from measurement of the chalk between the upper greensand and the base of these tertiaries, I find that at Dorking and Reigate the chalk is not above 400 to 450 feet thick, whilst above Godstone *it does not exceed a thickness of* 300 *feet*.

Fig. 7.—*Diagram showing the conditions that would have resulted from the deposition of the Cretaceous Beds on the edge of a shoal formed by the previous elevation of the Weald.*



a. Elevated mass of the Weald. 1 & 2. Lower Cretaceous strata, thinning out to the south, whilst the Upper strata overlap successively upon the Wealden rocks.
b. Cretaceous beds.

Fig. 8.—*Diagram showing the relative thickness of the Lower Cretaceous beds, and the denudation of the Chalk, over the Weald.*

c. Chalk.
d, *e*. Upper Greensand and Gault.
f. Lower Greensand.
g. Wealden.

[The lower beds of Chalk below *x* should have been represented as rather thicker and the Lower Greensand rather thinner.]

of the Upper Greensand period and at the dawn of that of the Chalk; still it was not of that extent to prevent the extension over the southern area of an important mass of lower chalk and of the middle chalk with flints. Neither the upper nor the lower chalk, however, possess that great development which they do in Herts and Cambridgeshire—the one apparently having been removed by denudation, and the other originally deposited in a thicker mass.

On either alternative, of a depression in Cambridgeshire or an elevation in Kent, the result would still be the same, in that we should have the chalk surface relatively higher and nearer to the sea-level in the latter than in the former county. This would favour the wearing down of the chalk by the action of the sea over the present area of the Weald, and as we see reason to believe that the chalk within that area was removed or reduced to a thin shell, it is probable that some of the underlying beds of the green-sand or even of the Wealden might have become exposed to the denuding action. See fig. 8.

There is no appearance, however, in the Lower Tertiaries of debris derived from any large mass of clay such as the Wealden, whereas the light-coloured sands, with traces of greensand and occasionally of carbonate of lime, forming the Thanet Sands, have a mineral character perfectly harmonising with a reconstruction out of the Upper Greensand chiefly, with the Gault and upper part of the Lower Greensand partially. It would thus seem that only these portions of the lower cretaceous series had, together with the Chalk, at that time been raised to the surface, and furnished materials for the Thanet Sands.

Again, we find in the next or middle division of the Lower London Tertiaries an enormous accumulation of round flint-pebbles, which, generally speaking, could not have been rolled and worn into their present shape on the spots in which they are now found. They were, I believe, formed during the deposition of the Thanet Sands, and afterwards spread out by other operations on the surface of these sands and incorporated with the strata formed during the period of the Woolwich and Mottled Clay series which immediately followed.

From the foregoing considerations it is probable that there was some extent of dry land, possibly an island, somewhere intermediate between a line drawn on the north from Farnham towards Canterbury, and on the south between Winchester and Newhaven, and extending eastward into the north of France *; and that the long-continued wear on its coast accumulated on the shores extensive banks of pebbles, whilst the finer sediment produced at the same time, in conjunction with the debris brought down by the operation of streams, formed at a distance from the land the strata of this oldest Eocene epoch †. Diagram fig. 8 illustrates this hypothetical view.

One reason for believing that this land formed an island is, that had the land stretched far east and west it must have reached beyond the chalk-district, and it is more than probable that the currents and tides of the sea would then have drifted the shore-pebbles from the older rocks in one of these directions, and mixed them up with those derived from the flints of the chalk, along some parts at all events of the line of coast; whereas in an island the cliffs of which consisted exclusively of chalk or of soft beds of greensand (if without drift-gravel), the flints would form the only material capable of resisting long wear and of furnishing the beach-shingle ‡. On this view alone can I account

* In his memoir "Sur l'Etendue du Système Tertiaire inférieure" in the north of France, M. Elie de Beaumont arrives also at the same conclusion respecting the existence of an island in the position of the present Wealden and Boulonnais during the formation of the Lower Tertiaries period, and gives a sketch of the geography of that period. (Mém. Soc. Géol. de France, vol. i. p. 111, and pl. 7. fig. 5.)

† The extent of this land, however, I believe to have been small compared with that of the period of the Woolwich fluviatile and æstuarine deposits, for all the remains of plants are in a very fragmentary state and not in any mass, as though large rivers were wanting and the land were drained merely by small streams and torrents; in confirmation of which view it is to be observed also that there are no distinct river-deposits with fluviatile shells in the Thanet sands, which fact shows that the materials were either derived from the wear of the coast or from small streams which would not effect the uniformity of character of the marine deposit. This might require an immense period of time, but of this we have evidence in those really wonderful accumulations of rounded flint-pebbles before mentioned. Further, we know that the Thanet sands are spread much more widely over the chalk than are the fluviatile series, in consequence probably of a further elevation of the land and the conversion into dry land of part of the adjacent sea-bottom at the latter period.

‡ There is, I am aware, some difficulty in determining the origin of these round flint-pebbles. They are evidently chalk-flints, but they present some characters rather distinct from those of the ordinary chalk-flints of the neighbourhood of London. The fossils found in them are very scarce and not very conclusive. Mr. Flower, who has examined with great care large numbers of these pebbles, considers them derived from some more distant locality, as their organisms

for the remarkable freedom from all admixture of pebbles of the older rocks* in the enormous flint-pebble beds of the Lower Tertiaries. It is to be observed also that we have no chert-pebbles, which may arise from its more splintery structure, or from the sea not having encroached so far on the land as to have reached the cherty beds of the lower greensand.

Thus the changes in the remarkable area of the Weald appear to date back to a period possibly far anterior to that even of the lowest tertiaries. While, however, I am inclined to extend the action of the subterranean forces acting along that axis to an epoch antecedent to that at present assigned to it, I at the same time consider, with many other geologists, that the chief disturbances are of comparatively recent date. I cannot think that that denudation of the Weald which tended to give it the present form, or even its main features, was coeval with a gradual elevation during the London Clay period, and that the debris of the Wealden clays drifted out during this prolonged denudation supplied the materials for this more important eocene deposit. The denudation, or denudations, resulting in the present peculiar structure of the Weald, I would rather place in the newer pliocene and the post-pliocene periods†. Still, as before mentioned, I believe that a portion of the Weald was elevated at the commencement of the tertiary period, and that there was a long-continued and gradual action of the sea on that coast (during probably a very slight progressive subsidence), unaccompanied by the operation of any large rivers from the land; for the spread of the Thanet Sands appears to have been effected more by marine currents and tidal action than by river transport, if we can judge by the facts stated above, that no distinct fluviatile beds have yet been found in them, and that their marine character is preserved over their entire area. Small streams must necessarily have existed, but none of power sufficient to accumulate distinct and independent groups of strata.

The changes, therefore, which took place in the Weald during this tertiary period were, I conceive, confined to the planing down of the chalk and part of the greensand, whereby a large mass of strata was removed from this area,—an operation which must have greatly facilitated the further changes which, at a later period, ended in producing the existing striking configuration of the surface.

These views with respect to the distribution of land and water at this geological epoch are in some measure corroborated by the evidence of organic remains, for it is curious that the fauna of the Thanet Sands seems to indicate that the temperature of the sea in this district was rather lower than at the subsequent period of the London Clay. We cannot of course argue conclusively upon this point, but, merely viewing the question generally, the limited number of

differ from those of chalk-flints around London. I hope he will shortly make public the result of his researches on this subject.

* Except a very few quartz-pebbles which may have come out of the chalk.

† I do not here enter into the general question of the elevation of the Weald, as that will form part of a paper on the "Drift" of the South of England, which I hope at a future period to lay before the Society.

species, the prevalence of *Cyprina, Astarte, Glycimeris,* and *Thracia* in these strata, combined with the absence of such genera as *Pyrula, Cancellaria, Voluta, Conus, Mitra,* and *Pleurotoma,* of the numerous large Cephalopods, and other animal and vegetable products of a presumed warmer climate, which abound in the London Clay, rather tend to point out the *probability* of a lower temperature in the sea of the Thanet Sands,—a fact in unison with the physical evidence of a sea open apparently to the north, and an island presenting a barrier to the south, and extending probably from the central portion of the present Weald to near the eastern borders of France. By itself this circumstance would not be entitled to much weight, but as it has been shown that the physical conditions under which such a result is possible, are in themselves probable, we may not unreasonably view them to a certain extent in the relation of cause and effect, and consider that the probabilities in favour of both are increased by the corroborative testimony thus afforded.

EXPLANATION OF PLATE XV.

The following sections show the dimensions and position of the Thanet Sands at intervals in their range from east to west,—from the point where they are best marked to that near to which they disappear beneath the London Clay. After a range of a few miles further west, they thin out altogether (fig. 3, p. 236). In soft strata of this description the pit-sections are rarely permanent, although there are some which are at present good and illustrative. The sections, therefore, selected to serve as types are those which appear most permanent, two of them being coast-sections and not liable to any very great change, and the others being works opened to supply a constant demand and likely to continue to be worked for many years. All the sections are actual ones, except that of Woodnesborough Hill, which is planned from surface-outcrops and wells, and is introduced to show the relation of the sands at Richborough to the outcrop of the Chalk, and the probable thickness of the Thanet Sands. The same observation applies to a small portion in the middle of the Upnor section No. 4.

Sect. 1. Gives a view of the end of the Isle of Thanet cliffs adjoining the valley of the Stour. Pegwell Bay is about two miles west from Ramsgate. Cliffs of chalk only are continuous round the other parts of the so-called island. At the point *a* in section, a remnant, 3 to 4 feet thick, of the basement bed of the Thanet sands, with the usual layer of green-coated flints, reposes upon the chalk. Between that point and *b* the cliff is a good deal obscured by debris and the slopes made for the road which descends to the beach; and at *b*, where the section can again be resumed, the cliff is composed entirely of the tertiary sands and drift, so that the junction of the chalk with this mass of Thanet sands is not seen. From the dip of the strata at *a*, the high level there of the small portion of Thanet sands, and the position of the main mass at *b*, it is probable that a fault occurs between these two spots; I have not, however, seen it exposed.

From *b* to the cliff end at *c* the section is continuous, and shows perfectly well probably all the series of the Thanet sands except the very highest and lowest beds. The lowest part, towards *b*, consists of about 10 feet of light-coloured, grey, and greenish clayey sands with traces of Plants and of a *Ditrupa* or *Dentalium*, and, continuing in the direction of *c*, pass up into 12 feet of more argillaceous and greener beds, then into 10 feet of laminated darkish grey sandy clay with a few fossils, succeeded by 8 feet of grey clayey sand, drying white, and with numerous small fossils. This is overlaid by 15 feet of dark clayey laminated

beds with a considerable number of well-preserved fossils. This last stratum and the remaining upper beds are described more in detail at p. 250, fig. 4. On the beach between *a* and *b* are numerous blocks of the sandstones and earthy concretionary limestones, many of which are very fossiliferous. At *a* the Tertiary strata dip about 2° W.S.W., and at *a* about 4° S.W.

Sect. 2. The branch-railway from Minster to Deal passes at the foot of the low hill on which Richborough Castle stands. A ballast-pit adjoining the line exposes the section here figured. The Thanet sands are seen rising at an angle of about 2° to 3° from beneath the sands of the middle division of the lower London tertiaries; there are here, however, so few distinctive features between them, that the separation is not at first easily recognized; a careful search will, however, detect a few peculiar fossils in the middle series, and in the Thanet sands the fossils are abundant, but very friable, at point *a*. For details of this section see fig. 5, p. 251. Between this and section No. 1 there is only the valley of the Stour with its marsh-lands. The strata in both places dip towards this valley.

Proceeding southward there is a tract of flat ground without sections, and the surface then rises to the ridge of low hills which run from Sandwich to Wingham and Canterbury. On the eastern extremity of the range stands Woodnesborough Church, in descending from which towards Sandwich the sides of the lane exhibit a tolerably good section of the Thanet sands with fossils, and overlaid by the sands of the middle division. On going down the hill in the other direction, the chalk is seen cropping out from beneath the Thanet sands: this part of the section is rather shortened; it represents a distance of 1½ mile. The height of the hill is only approximate.

Sect. 3. This is the finest section of the Lower Tertiaries in the London district. Herne Bay is about 1½ mile west from the spot where this section commences. At a short distance east of the town, the London Clay rises and forms a sloping and grass-covered cliff for nearly a mile; the talus then becomes less and the section clearer, showing a considerable mass of the London clay, with few or no fossils, except casts of fragments of wood in iron pyrites. A little way further, the sands (3) forming the upper division of the lower London tertiaries rise at a small angle (2° to 3°) from beneath the London clay; they abound in fossils, but in an extremely friable state, except where preserved in the tabular calcareous blocks, *a*, or in concreted portions of the conglomerate, *b*. (For a description of this bed and its fossils see my paper "On the Basement-bed of the London Clay," in the Quart. Journ. Geol. Soc. vol. vi. p. 265.) This division is underlaid by the middle group, which is here composed of three closely allied strata, consisting at *c* and *d* of an upper bed of argillaceous greensand, a middle one in which brown clay predominates, with a few small flint-pebbles, and abounding in traces of vegetable remains, and with many fragments of lignite, and a lower division marked by coarse green sands; but as these beds trend towards *d* [the left-hand *d* which should have been *e*] they appear rather less argillaceous, and as a very light green sand, the line of demarcation between them and the Thanet Sands being, in consequence, at the end of the cliff towards the Reculvers very indifferently marked. Fossils are rather scarce; the few however that occur are the same as those found in stratum 4 at Richborough. This group, as well as "4" in the Upnor and Woolwich sections, will be described more in full in the next part of this paper. Owing to the great similarity in mineral character between the lower part of this middle division and the upper part of the Thanet Sands in these cliffs, their line of separation is often very indistinct.

Immediately east of the Bishopstone ravine the "Thanet Sands" rise from beneath the middle group (4). The first bed consists of yellowish sands with only a few patches of shells, but with numerous

soft impressions, and varying in thickness from about 15 to 20 feet. Beneath them is a nearly continuous, tabular, light grey, hard, concretionary, calcareous sandstone, 1 to 2 feet thick, with few fossils, but often covered with large vermiform casts. Next follows 4 to 6 feet of light-coloured argillaceous sands with a few fossils. Below this a darkish grey semi-indurated clayey sand crops out, and is well exposed between high and low water mark. It abounds in characteristic and well-preserved fossils of the Thanet sands, by far the most abundant shell being the *Cyprina Morrisii*. This stratum forms the base of the cliff nearly to the Reculvers, and is throughout marked by the same fossils: at the same time, the top bed of the Thanet sands, which at first contains only a few shells, becomes more fossiliferous, and near there abounds in well-preserved but very friable shells, chiefly the *C. Morrisii*, together with the *Cucullæa crassatina*, *Thracia oblata*, and many others comparatively rare (see list, p. 248). The cliff ends at the Reculvers; the marsh-lands separating this spot from the Isle of Thanet then intervene; at Birchington the cliff rises again, but consists of chalk without any capping of tertiary strata. The relation, however, of the Thanet sands to the chalk was shown by a well dug at the Reculvers some few years since. I was informed that the chalk was reached at the depth of about 70 feet, after traversing sands which became more clayey in descending, and with shells in patches throughout. This position of the chalk is shown on the left of the section.

Sect. 4. Just below Upnor the hills approach close to the left bank of the Medway, and the numerous pits opened for ballast-sand exhibit some good sections of the lower tertiaries. (For a description of Stratum "3," see paper before cited, Quart. Journ. Geol. Soc. vol. vi. p. 263.) The middle group "4" is considerably expanded, and consists almost entirely of sands; the upper bed is fossiliferous and of a light yellow colour, and the lower bed is of a very light tinge of yellowish green, with subordinate beds of small flint-pebbles, but without fossils. Between these two sands are a few feet of dark grey laminated clays and sands, full of *Cyrena cuneiformis*, *Melania inquinata*, and some other fresh or brackish water shells. The Thanet sands rise from beneath the sands "4" at the pit (at *b*) just behind Upnor village, but the characters of the two groups are here so much alike, that it is not easy at first to distinguish them apart, especially as neither contain fossils. They may then be traced at intervals along the river-bank, by Upnor Castle, to a chalk-pit on the foot-road to Stroud, where the lowest beds are seen reposing on the chalk, with the usual green-coated flints at their base. They are here much mixed with fine greensand, and are also without fossils. The dip at Upnor is about 3° N.E.

Sect. 5. This is a well-known locality and has been frequently described, chiefly however with reference to the upper beds, which abound in the so-called Woolwich shells. (For particulars of this section and its fossils I beg to refer to Dr. Buckland's paper, Trans. Geol. Soc. vol. iv. p. 284, and to the Rev. Mr. De la Condamine's paper in the Quart. Journ. Geol. Soc. vol. vi. p. 440.) The Thanet sands are here fine-grained, siliceous, and without organic remains, if we except traces of plants (in fragmentary casts and impressions), and the cast of the *Pholadomya* mentioned by Mr. Morris (see text, p. 265). The upper part of these sands are nearly white, very loose, and almost purely quartzose; in descending they become tinged ash-grey and yellow, and mixed with a small proportion of argillaceous matter, and with a perceptible quantity of greensand in their lower part. The basement-bed as usual is an impure greensand, with green-coated flints, and is only reached occasionally on the floor of the pit. The view here given is one at right angles to the road, and was exposed a few years since; this part of the pit is not now worked, and the sands are almost entirely sloped over. The present works are just round the end of this section. The Basement Bed of the London Clay is given with a query, as I am not yet sure whether

the bed here so marked may not be an upper member of the middle division.

In the above sections the principal masses only of drift are shown. In No. 2 there is a drift in the valley between Richborough and Woodnesborough Hill. In No. 3, besides the drift marked on the top of the cliffs, there are some detached masses on the lower cliffs between *d* and the Reculvers. In No. 4, patches of a mixed drift occur occasionally in places on the slope of the hill above *b*, and a thick mass of brick-earth drift is worked at the base of it. The same, with gravel and mammalian remains, is largely developed at the foot of the chalk hill to the left of the section.

Description of some Fossil Shells *from the* Lower Thanet Sands. By J. Morris, F.G.S.

Sanguinolaria Edvardsii, n. sp. Plate XVI. fig. 1.

Testâ ellipticâ, compressâ, inæquilaterali, transversim striatâ; anticè attenuatâ, posticè rotundato-truncatâ; umbonibus prominulis.

An ovate-lanceolate, inequilateral shell, somewhat compressed, marked by numerous fine, sharp, raised striæ, which are more prominent towards the lateral margins; anterior extremity attenuated, posterior extremity rotundato-truncate. Width rather more than twice the length.

Named in compliment to Mr. Frederick Edwards, of Hampstead, to whom we are indebted for much information on Tertiary Palæontology.

Herne Bay. Specimen figured, from Mr. Edwards's Collection.

Glycimeris Rutupiensis, n. sp. Plate XVI. fig. 2.

Testâ transversâ, elongatâ, subæquilaterali, subconvexâ, transversim striatâ; lateribus rotundatis; margine medio subdepresso, margine cardinali calloso; umbonibus obsoletis.

A transversely elongated, nearly equilateral, and somewhat convex shell, with rounded extremities, the dorsal and ventral margins parallel; both valves having a slight depression in the middle, which extends to the ventral margin; lines of growth numerous, sharp. Width 2½ times the length.

This shell is distinguished from *G. angusta*, Nyst, by its more equilateral form, and by the dorsal margin being less angular, and the posterior extremity more rounded.

The species of this genus are very rare in a fossil state, having been only found at present in the Tertiary strata. The one above described is the most ancient known form, the other belongs to the Crag of Belgium and England.

Herne Bay. Mr. Edwards's Collection.

Panopæa granulata, n. sp. Plate XVI. fig. 3.

Testâ ovato-oblongâ, transversâ, inæquilaterali, granulatâ, transversim irregulariter striatâ vel undulatâ; margine medio subcompresso; lateribus rotundatis; umbonibus minimis, incurvis.

An ovate, elongated shell, with rounded extremities; somewhat cylindrical; the middle of both valves depressed near the ventral

SCALE

Distances

10 Inches = 1 mile

Heights

1 Inch = 100 feet.

1. Drift
2. London Clay
3. Upper .....
4. Middle .....
5. Lower (Thanet Sands)

Lower London Tertiaries

6. Chalk

1 2 inches

SECTI

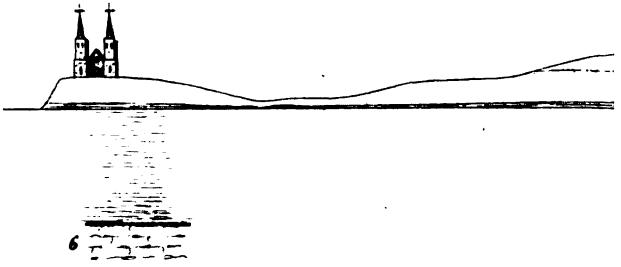
to illustrate M.

Paper on the The

S.S.W.

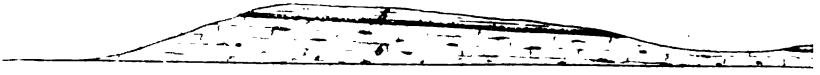
E.

The Reculvers.



4. General

S.



liff at Pegwell Bay

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relation to the p

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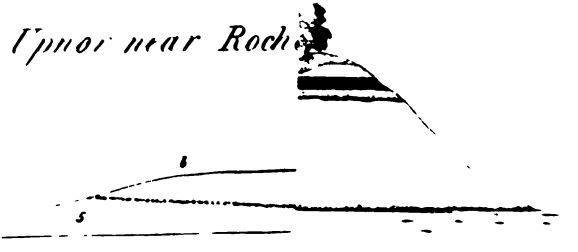
W.

olwich . West Kent

Upnor near Roch



margin, which is rather straight; surface minutely granulated, and transversely striated and undulated. This shell is difficult to distinguish from the *P. intermedia*, Sow., and appears to be intermediate in general form and character to that species and the *P. corrugata*, Sow. (Dixon's 'Fossils of Sussex'); the ligamental and ventral margins are straighter, and the shell more compressed ventrally than *P. intermedia*. The surface is also minutely granulated, which character has not been observed in the other species.

The difference of habitat may, however, have modified the forms assumed by these shells, producing only local varieties.

The *P. intermedia* of Nyst appears to be distinct from the English forms.

Herne Bay. Mr. Bowerbank's Collection.

PHOLADOMYA KONINCKII, Nyst. Plate XVI. fig. 4.

(Nyst, Coq. Foss. Belgiques, p. 50. t. 1. f. 9.)

It has been considered advisable to refigure this shell, as it has not been previously described as occurring in England; and especially, as this species has been sometimes mistaken for *P. margaritacea*, Sow. But, from comparison with authentic specimens, we have considered this to be a variety of *P. Koninckii*, Nyst, a species very characteristic of the Lower Tertiaries of Belgium.

Herne Bay. Mr. Prestwich's Collection.

CYTHEREA ORBICULARIS, Edwards, MSS. Plate XVI. fig. 5.

Testâ tenui, orbiculari, depressâ, lentiformi, subæquilaterali, vix transversâ, concentricè striatâ vel sublamellosâ; umbonibus minimis, subrecurvis; lunulâ vix notatâ.

A slender, orbicular shell, with faintly marked concentric striæ or lines of growth, becoming occasionally lamelliform; the umbones are small and slightly recurved; the sinus in the pallial impression is obtusely angular; the lunule is nearly obsolete.

This species varies slightly in form, being sometimes transversely oval, the beaks much nearer the anterior margin, the posterior side more compressed, the cardinal margin straighter and less angular, than in the typical form.

This shell appears to be distinguished from *C. Bellovacina*, Deshayes, by the posterior margin being shorter and less angular, and the general form being more orbicular and symmetrical.

Herne Bay. Mr. Edwards's Collection.

ASTARTE TENERA, n. sp. Plate XVI. fig. 6.

Testâ subtrigonâ, depressâ, tenerâ, inæquilaterali, concentricè irregulariter rugosâ; latere postico compressiusculo; umbonibus submedianis; lunulâ ovatâ, profundâ, lævigatâ; marginibus crenulatis.

A somewhat trigonal and rather fragile shell; the posterior side being slightly compressed and angulated; the surface marked with concentric symmetrical ribs and intervening furrows in the young state, which become irregular both in form and distance in the adult shell, giving it a rugose appearance; the intermediate furrows are faintly

striated; the beaks somewhat acute, and recurved over the lunule, which is elliptical and smooth; the ligamental area excavated; the margins of the shell are crenulated.

A species readily distinguished from the *A. rugata*, Sow., of the London Clay by the general form, thinner shell, and less rugose surface of the valves.

Herne Bay. Collections of Messrs. Edwards and Bowerbank.

LEDA SUBSTRIATA, n. sp. Plate XVI. fig. 7.

(Compare *Nucula striata*, Lam., Desh. Coq. Foss. t. 42. f. 4–6.)

This shell, collected by Mr. Prestwich from the Thanet Sands at Richborough Castle and Pegwell Bay, is difficult to distinguish from *Nucula* (*Leda*) *striata*, Lam., which it resembles in general form, but is rather longer in a transverse direction, and the striæ differ a little and are interrupted towards the posterior margin in some of the specimens examined.

PECTEN PRESTVICHII, n. sp. Plate XVI. fig. 8.

Testâ tenui, compressâ, radiatim obsoletè costatâ; costis 30–36, subequalibus; interstitiis obliquè irregulariter striatis; auriculis inæqualibus, radiatis.

Shell thin, compressed; margin orbicular, with a rectangular beak; radiated with 30–36 very slightly raised ribs, distantly imbricated, the intervening furrows twice as large as the ribs, irregularly and obliquely striated; ears unequal, with three or four radiated costæ.

Richborough Castle. Collected by Mr. Prestwich.

SCALARIA BOWERBANKII, n. sp. Plate XVI. fig. 9.

Testâ elongatâ, turritâ, imperforatâ; anfractibus 9–10, ventricosis, rotundatis, suturis distinctis, longitudinaliter costatis; costis 18–20, subacutis, interstitiis transversim striatis; anfracto ultimo carinifero; aperturâ rotundatâ.

An elongated, turreted, rather thick shell, with nine to ten ventricose volutions, longitudinally costated; costæ eighteen to twenty, somewhat acute, and slightly oblique, the ribs as well as intervening furrows transversely striated; the last volution carinated.

The ribs on the lower volutions are sometimes divided and more irregular than on the upper ones.

This species is closely allied to, if not identical with, a shell obtained by Sir C. Lyell from the Lower Tertiaries of Belgium (*Système Landenien* of Dumont).

Herne Bay. Mr. Bowerbank's Collection.

TROPHON SUBNODOSUM, n. sp. Plate XVI. fig. 10.

Testâ turritâ, ovato-fusiformi, transversim tenuissimè striatâ, anfractibus convexis, subcarinatis, supernè angulatis, carinâ subnodosâ; aperturâ ovatâ; columellâ recurvâ; canali brevisculo.

Shell turreted, ovately fusiform, transversely striated, and faintly decussated; volutions convex, upper part subangulated and nodulous; aperture ovate, with a short, open and recurved canal.

Herne Bay. Mr. Bowerbank's Collection.

AMPULLINA SUBDEPRESSA, n. sp. (not figured).

Imperfect specimens of a shell (from Pegwell and Herne Bays) have been obtained, which bear considerable resemblance to *Globulus* (*Ampullina*) *depressus*, Lamk, sp., from Barton; but the spire is not so elevated, and the umbilicus is much more open; it is possibly only a local variety.

CRISTELLARIA PLATYPLEURA*, n. sp. Plate XVI. fig. 12. Diam. $\frac{1}{16}$ inch.

Testa ovata vel subcircularis, posticè rotundata, anticè angulata; margo acutus, cristâ pellucidâ instructus: loculi 9, plani, irregulariter arcuati, ultimus anticè excavatus; suturæ valdè costulatæ; umbo densus, prominens; apertura rotunda, margine granulato.

In a young state this *Cristellaria* is ovate, and has its cells more regular, and the umbo and ribs less thickened and distorted.

CRISTELLARIA WETHERELLII, n. sp. Length $\frac{1}{15}$ inch.

Testa oblonga, anticè acuta, basi spiraliter involuta, rotundata; margo arcuatus, acutè angulatus; loculi 12, lævigati, angusti, antici infernè marginati, ultimus subconvexus; suturæ planæ, pellucidæ; apertura rotunda, margine radiato.

In the young state this *Cristellaria* is subovate, the umbo being almost central; but in the more advanced stage of growth, the chambers having gradually left the spiral for an almost straight direction of growth, the inner or inferior margins of the cells cease to join the umbo, and the form of the shell becomes elongate. One old specimen quite assumes the form of a *Marginulina*.

The *Cristellaria* from Mr. Wetherell's collection, and belonging to the London Clay, figured by Mr. Sowerby in the Trans. Geol. Soc. 2nd ser. vol. v. pl. 9. fig. 19, represents one stage of growth of this species.

ROSALINA MARIÆ, n. sp. Plate XVI. fig. 13. Diam. $\frac{1}{30}$ inch.

Testa suborbiculata, depressa, rugosa; supernè sex-lobata, vix umbilicata; subtus umbilico lato, aperturis subvalvulatis circumdato; margo rotundatus; loculi 6, subconvexiusculi, irregulariter triangulati, ultimus anticè valdè convexus.

POLYMORPHINA AMPULLA, n. sp. Plate XVI. fig. 14. Diam. $\frac{1}{40}$ inch.

Testa subglobosa, lævigata, supernè in rostro brevi producta, basi obtusa; loculi pauci, convexi; suturæ lineares; apertura rotunda, excentrica, radiata.

[It is not at all improbable that Boys and Walker, as well as Montagu, have figured and described several of the Foraminifera of the Thanet Sands of Sandwich as recent forms.—T. R. J.]

* These new Foraminifera are described by Mr. T. Rupert Jones.

EXPLANATION OF PLATE XVI.

Fig. 1. Sanguinolaria Edvardsii, *Morris.*
Fig. 2. Glycimeris Rutupiensis, *Morris.*
Fig. 3. Panopæa granulata, *Morris.*
Fig. 4. Pholadomya Koninckii, *Nyst.*
Fig. 5. Cytherea orbicularis, *Edwards.*
Fig. 6. Astarte tenera, *Morris.*
Fig. 7. Leda substriata, *Morris*, magnified.
Fig. 8 *a*. Pecten Prestvichii, *Morris.*
Fig. 8 *b*. ——— ———, portion magnified.
Fig. 9. Scalaria Bowerbankii, *Morris.*
Fig. 10. Trophon subnodosum, *Morris.*
Fig. 11. Ovoidal bodies filling tubular cavity in sand (see p. 247).
Fig. 12 *a*. Cristellaria platypleura, *Jones*, magnified.
Fig. 12 *b*. ——— ———, edge view, magnified.
Fig. 13 *a*. Rosalina Mariæ, *Jones*; under surface, magnified.
Fig. 13 *b*. ——— ———, edge view, magnified.
Fig. 14 *a*. Polymorphina ampulla, *Jones*, magnified.
Fig. 14 *b*. ——— ———, seen from above, magnified.

MAY 5, 1852.

Capt. R. M. Westmacott was elected a Fellow.

The following communications were read:—

1. *On the* TERTIARY FORMATIONS *of* BELGIUM *and* FRENCH FLANDERS. Part I. *The* PLIOCENE, MIOCENE, *and* UPPER EOCENE. By Sir C. LYELL, F.R.S., V.P.G.S.

[This will be printed with Part II. "On the Lower Tertiaries of Belgium," read May 19, 1852.]

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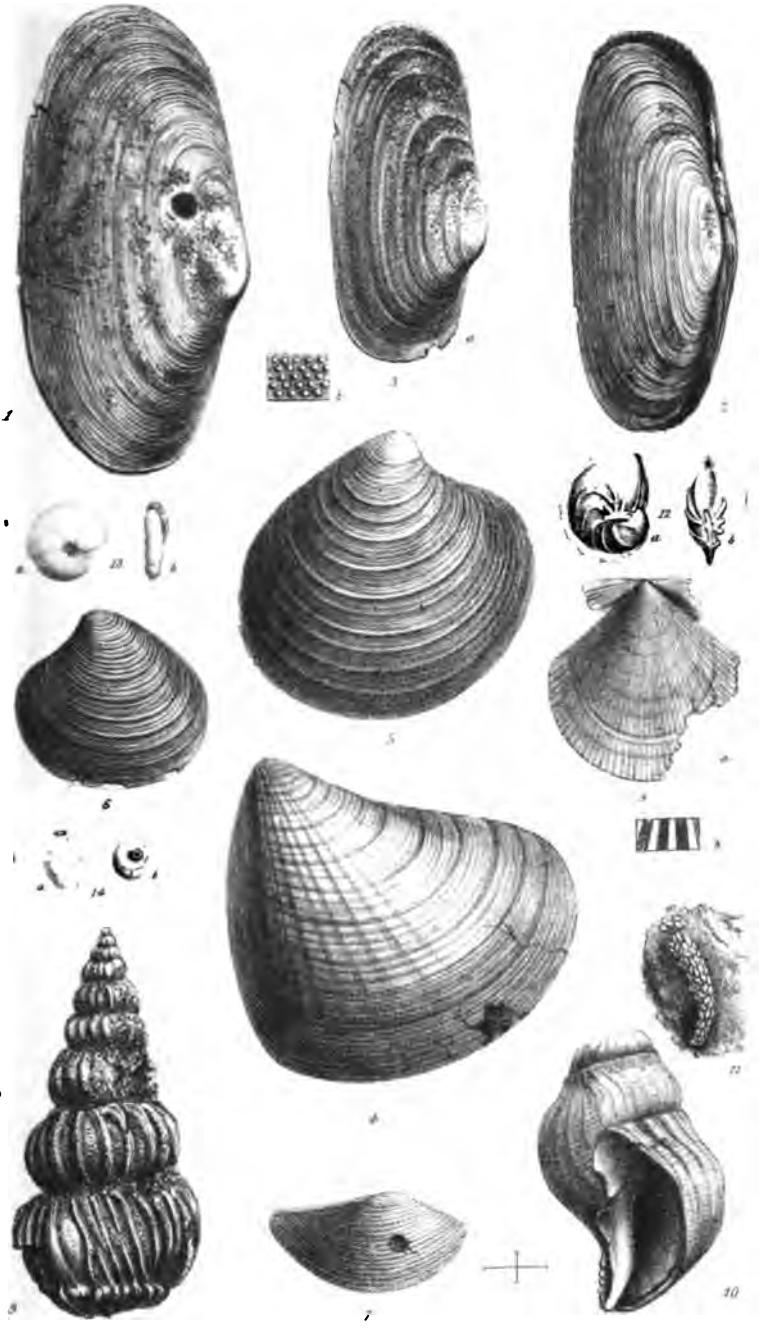
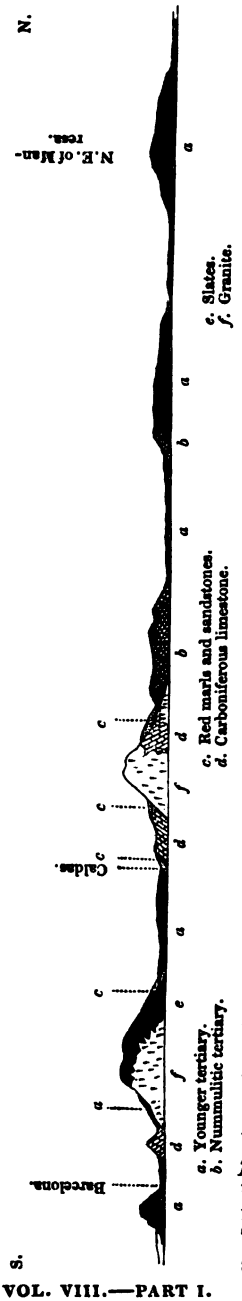
2. *On the* GEOLOGY *of* CATALONIA. By S. P. PRATT, Esq., F.R.S., F.G.S. &c.

THE general aspect of the Spanish Province of Catalonia is a series of hills, which take a direction from the north-east to the south-west, nearly parallel to the coast; they are separated from each other by undulating plains or valleys of nearly the same width as the ridges, varying from five to twelve miles. These hills occasionally rise to a considerable elevation, from 2000 to 3000 feet. As great disturbance has taken place near the chain of the Pyrenees, these parallel ridges do not assume their predominant character nearer than about twenty miles from the base of these mountains; but even beyond this distance, they are considerably disturbed here and there throughout their extent by igneous action and the protrusion of masses of granite. The pass of the Pyrenees by Bellegarde to Jonquera represents the general character of several other ridges in the province, the base being granite, covered by gneiss, and surmounted by very thick deposits of schistose beds, with occasional masses of limestone and red marly sandstone.



THANET SANDS FOSSILS.



General Section across Catalonia.

The road between Jonquera and Gerona, by Figueras, is chiefly over an undulating plain, varied by a few low ridges of hills; the plain itself being covered by a deep alluvium, composed chiefly of disintegrated granite, which rock rises in several places a few feet above the surface. The low ridges of hills alluded to consist of an impure sandy limestone, covering in places a red marly sandstone. On approaching Figueras, these hills rise considerably to the west, and contain fossils of the lower oolitic period; some of the species appear to be closely similar to those of the inferior oolite of this country. This is an important fact, as the whole of this district has been coloured in the map of France as belonging to the cretaceous period. A very extensive plain extends from Figueras to the north-east and south, varied in a few places by low and very limited hills, composed of alluvial masses of various epochs. This plain extends towards Gerona, but it is greatly disturbed for about ten miles at half the distance, and is intersected by very deep narrow valleys or fissures, in which are found numerous masses of angular granite, porphyry, and lava. After passing this disturbed district, the plain extends to Gerona, where a lofty ridge, nearly 3000 feet high, suddenly rises; which, stretching nearly eastwards to the coast, appears to form a connection with the most southerly of the parallel ridges before alluded to. This high ridge, near Gerona, is composed in the lower part of thick beds of schist, having a metamorphic character. A few outbreaks of granite at a low elevation have been noticed along the line. The schistose beds are covered by thick deposits of limestone, and above them is a red marly sandstone. In the limestone a few compressed fossils are found, consisting chiefly of Encrinite stems, and a very few bivalve shells, probably *Brachiopoda*. The sandstone is covered at nearly the same inclination with numerous calcareous deposits of the early Tertiary period. The lower beds of the latter contain several species of *Foraminifera*, with a few small

Nummulites, the number of latter increasing very much in the upper beds.

I will now give a general description of the several ridges above alluded to. That which runs along the coast rises a few miles to the south of the Bay of Rosas, and continues a short distance beyond Barcelona. In its northern part, as far as Blanes, and at a few points farther south, it forms high cliffs on the sea-shore, composed entirely of granite. To the south of Blanes, the granite is overlaid by schistose beds of various thickness, sometimes of several hundred feet: these chiefly cover the north-western side of the ridge, and extend into the plain on that side; on advancing southwards, however, the schists increase on the south-eastern side. These schistose beds are in many parts covered by limestone, varying very much in extent and thickness, and also by a red marly sandstone, which overlies the limestone, though occasionally it rests on the schist, when the limestone is wanting. The granite has been disturbed in several places (subsequently to the deposition of these rocks) by the upheaval of porphyritic masses, and by the intrusion of granitic veins of great extent and considerable variety. The chief disturbance has taken place near Calella, where a mass of porphyritic rocks has acted upon the ridge. No fossils have been found in the schistose beds, which in many places have been considerably metamorphosed, and are penetrated in numerous places by granitic veins to a great extent. The thickness of these beds increases very much to the south-west; and near Barcelona they form two-thirds of the upper part of the ridge. The limestone also varies considerably in character, from a hard crystalline mass to a rock of a slaty character. The fossils found in it are very rare, and so much altered in structure that it is difficult to ascertain their genera; they chiefly consist of Encrinite stems, *Orthoceratites*, without specific character, and a few obscure *Brachiopoda*. Two very limited deposits of Coal have been found in this limestone, at Malgrat and Montghat; in the latter place, the limestone, from a mixture of carbonaceous particles, is nearly black for a short distance. It is covered to a very limited extent by a red marly sandstone, which, however, has considerable development to the south-west, which will be again mentioned. Near Montghat, and about ten miles to the north of Barcelona, there is a considerable deposit of this sandstone, forming a low ridge at the base of the granite ridge and between the latter and the coast. The sandstone ridge, from several local appearances and its metamorphic character, appears to have been elevated at a more recent period; and it contains a bed of gypsum, above 100 feet thick, which has been extensively worked. A plain, from half a mile to about four miles in width, lies between the granite ridge and the coast. This plain is covered to a considerable depth, from 30 to 50 feet, with the debris of the hills which bound it, mixed up with many thin horizontal layers of calcareous matter, containing a few freshwater and land shells. Close to Barcelona, which is about three miles from the granite ridge, rises Mount Juich, a hill about 700 feet high; it is composed of numerous beds of sandstone, conglomerates, and impure

sandy limestone; all these beds contain fossils, which appear to be of the Miocene period. The lower beds are highly inclined, of a hard crystalline structure, contain large masses of jasper, and appear to have been acted upon by heat, although no igneous rocks are seen. They are interstratified with thin beds of white clay and fuller's earth. The limestone beds, which contain numerous fossils, and have not been similarly acted upon, become nearly horizontal on the upper part of the hill and on approaching the plain which lies between it and the granite ridge behind Barcelona. The stratified alluvium which covers the plain in nearly horizontal beds, rises several hundred feet on the sides of the two hills which bound it, and has been disturbed in the same degree with the beds upon which it lies; particularly so on the granite ridge, which penetrates it in several places. It appears, therefore, probable that the elevation of these hills has taken place subsequently to the deposition of this alluvial deposit. In several deep fissures which cross the plain, granite is seen forming its base. The granite reaches the north bank of the Llobregat, and is seen no more except at a few points just above the surface on the other side of the river. On each side of this river, about two miles from its mouth, the red sandstone becomes considerably developed, covering the hills to a considerable thickness, and extending to the north-west as far as Montserrat. This is one of the most magnificent mountains in Spain; it attains the height of above 6000 feet, and is composed of numerous layers of both fine and coarse sandstone, alternating with thick conglomerate-beds. The red sandstone extends also to the south-west, covering the ridges of hills which extend as far as the Ebro.

To the north-west, and nearly parallel to this ridge of granite, schist, limestone, and sandstone, there is a plain about ten miles wide, with an irregular and undulating surface. It is bounded by another ridge which rises near Gerona, and extends nearly to the north bank of the Llobregat. Near Gerona the latter ridge has been much disturbed, and separated into several low hills by the uprising of granite and more recent igneous rocks. It is entirely composed of tertiary deposits, and all that part of it near Gerona and upon which the city is built is extremely nummulitic. To the north of the city, these beds rise to the height of about 300 feet, lying upon the red sandstone above described, but soon separating from that deposit, they form a series of low hills, which gradually sink into the plain five or six miles east of Gerona. Other low ridges, which run nearly parallel to these at a very short distance, are composed of the same beds, almost entirely nummulitic; and there are others beyond, farther west, containing numerous tertiary fossils also of the Eocene period. These low ridges have been considerably disturbed by the upheaval of large masses of lava, containing much olivine, and have every character of a recent origin. In many places this lava is seen beyond the hills, and forms extensive, perfectly flat, and almost naked plains.

Still further west, at the distance of nearly eight miles, another much higher ridge rises nearly parallel to those already described. It contains many tertiary eocene fossils, but without *Nummulites*. This

ridge also has been much disturbed and elevated by the upheaval of masses of granite and porphyry of considerable extent; indeed the whole district between this point and the base of the Pyrenees has been so much disturbed, that it requires considerable time to map its geological features correctly. On proceeding to the south-west from Gerona the country is also much disturbed in several places, but to a more limited extent, as far as the neighbourhood of Vich. On approaching this place, the tertiary ridges become very much developed, and extend with little interruption, except at a few points, to the neighbourhood of the Llobregat, forming in several places hills of considerable height. Beyond this river a considerable change takes place, but the ridges may be traced onwards to near Villa Franca and Tarragona. A little to the south-west of Vich the main ridge is divided, for the distance of a few miles, by a narrow but deep valley; the portion to the east is composed of granite hills, rising in one place to the height of about 2000 feet; in other parts, however, the granite is much lower, and is composed of an arkose, having a very compact character, and formed of sharp-edged masses of granite of a very different character from the great mass. It is covered in several places by a limestone, highly inclined, bearing evidence of igneous action, and containing a very few of the same fossils (Encrinite stems) as those in the limestone overlying the high ridge, previously described. The second portion of the ridge is composed of numerous calcareous and sandy beds, differing much in character, but apparently of the same age, as nearly all contain *Nummulites*. The beds are highly inclined where they approach the granite, and become nearly horizontal at a short distance from it. They have a thickness of from 700 to 1500 feet. Some of the beds contain numerous fossils, of the same species as those observed in the hills near Gerona, and very similar to those found at Biarritz in France. This ridge is divided in several places by very deep narrow valleys or chasms, which give vent to numerous powerful streams. On the north-west side it is covered by a bed of calcareous rock containing numerous specimens of a large *Cerithium*, very similar to the *C. giganteum* of the Paris basin, and descending into the plain which lies between this ridge and another distant about ten miles. This plain is much less disturbed than the other, and the ridge which bounds it to the west is lower, and of a later tertiary period, probably the Miocene; the majority of the fossils, however, are peculiar to it. It extends to the south-east, beyond Montserrat, and thence to the north-west of Villa Franca.

To the south-west of the River Llobregat, the character of the country changes considerably, for although a succession of plains and ridges still continue as far as the Ebro, yet they are considerably modified, becoming much more irregular in form and proportion. The ridge near the coast to the south of the mouth of the Llobregat is much wider, more irregular in its composition, and terminates almost entirely beyond Villa Nueva. It is composed chiefly of very thick calcareous beds, partially covered by the red marly sandstone already noticed. The fossils are very rare and obscure in their

character, except in the neighbourhood of Villa Nueva, where some very large deposits of tertiary fossils are found, with thick beds full of minute *Foraminifera*, without any *Nummulites*. Mixed with these are found some fossils which have been considered as cretaceous, and have been met with in the Pyrenees. Beyond Villa Nueva, close to the coast, the ridge is but a few feet high, but as it approaches Tarragona it rises in height, and tertiary fossils of a much later period are abundant in it. To the north-west of Villa Franca there are several ridges of limited extent, of similar character to those described as occurring north of the Llobregat, except that the fossils are rare; but as a few *Nummulites* are found in them, their relative age is determined. One of these ridges extends to Tarragona, where it rises to some height, and continues several miles westward. The upper part of these hills is covered near the coast by numerous fossils of a recent period. Underneath these beds are found some thin strata, containing a very few *Nummulites*; and these tertiary beds overlie a mass of calcareous rock which contains a very few *Belemnites* and small *Ammonites* of a cretaceous character, the only specimens belonging to this period which I have observed in the whole Province of Catalonia. The latter rock is most distinct in the city of Tarragona, where, however, it does not rise to the height of more than 20 feet, and runs along the coast to the south-west in isolated hills of the same height. A short distance to the south-west of Tarragona, near Reus, there is another ridge of much greater elevation, with a granite base, overlaid by tertiary deposits of considerable variety, and extending to within a few miles of the Ebro.

May 19, 1852.

The following communications were read:—

1. *On the* Origin *of the* Soils *which cover the* Chalk *of* Kent. By Joshua Trimmer, Esq., F.G.S.

Part II.*

In a Report on the Agricultural Geology of England and Wales, lately published in the 'Journal of the Royal Agricultural Society of England,' I have collected, from the Reports to the Board of Agriculture and other agricultural authorities, evidence of the existence of a great variety of soils, calcareous as well as non-calcareous, on the surface of the Chalk in its range through England. It is thus proved by the testimony of a number of independent observers, that calcareous soils are the exception, and are confined to certain elevations and forms of surface.

I have also, in a recent communication to this Society, "On the

* The communication which forms Part I. of these Notices of the Superficial Geology of the S.E. of England was read November 20, 1850. See Quart. Journ. Geol. Soc. vol. vii. p. 31.

Origin of the Soils which cover the Chalk of Kent*," combated the dogma, that these soils were formed by solution of the rock *in situ*, and that the non-calcareous varieties are the residuum of such hypothetical solution.

In opposition to these views I contended, that such soils were formed by aqueous transport of some kind or other, the nature of which I did not then attempt to define; nor do I now attempt to define it beyond this: that, if atmospheric, it was different from ordinary atmospheric action; if marine, it was different from ordinary marine action; that the phænomena produced were different from those which, in the case of the Till or lower erratics, I attribute to the action of shore-ice on sinking land, and different from those which, in the case of the sand and gravel of the upper erratics, I attribute to the action of ice floating in a more open sea.

Neither do I now attempt to define the date of these operations in Kent, beyond this: that many of the phænomena are closely allied to, if not identical with, those which, north of the Thames, took place after the desiccation of the bed of the glacial sea, and after pleistocene England had been re-inhabited by some of the large mammals, now extinct, which had flourished in pliocene England, before its submergence beneath the glacio-pleistocene sea.

In proof of the formation of the soils on the chalk of Kent by aqueous deposit, I adduced a section in which a road-cutting, near Hartley Rectory, exhibited irregular alternations of dark tenacious clay containing unabraded flints, with light-coloured sandy loam and seams of rounded eocene pebbles. That section was on the descent towards a valley communicating with the valley of the Darent, from the elevated plateau of chalk which extends to the Weald denudation. It has therefore been argued that this section, being on the slope of a hill, merely represents an accumulation of the nature of a talus, although I stated that similar deposits constitute the surface-soil for miles on the summit of the plateau.

I shall now draw attention to the soils on some of the highest summits of the chalk, at an elevation of about 700 feet, near the edge of the precipitous escarpment overhanging the Weald denudation, or, more correctly, the Vale of Holmsdale, lying between the chalk and the Wealden.

By reference to the Ordnance Map it will be seen, that the road from Farningham to Wrotham ascends the chalk from the valley of the Darent, along a combe. The steep side of the combe is covered with calcareous soils, for the most part white, but intermixed with some irregularly distributed patches of loams, light-coloured, brown, and of various intermediate shades of colour, but all more or less calcareous. The summit attained, these calcareous soils cease, and are replaced by dark brown non-calcareous loams, of depths varying from less than one to more than three feet, and of various degrees of tenacity. About the fourth mile from Wrotham, the tenacious varieties prevail. They appear to belong to that class of soils, which Boys, the author of the Report on this County, describes as

* *Loc. cit.*

forming, in West Kent, "clay on the tops of the chalk-hills, much mixed with flints, cold and tenacious, and requiring six strong horses to plough an acre a day, and when not ploughed till dry in the summer, hardly practicable with eight horses: depth 8–14 inches, on chalk rock, with yellow clay between in some places."

These soils of West Kent appear to answer to those which, in East Kent, he calls "strong cledge, a stiff tenacious earth, with a small proportion of flints, and at some places small patches of chalk; 6–10 inches deep on the tops of the hills, and resting on a hard rock of chalk. When wet," he adds, "it sticks like bird-lime, and when thoroughly dry, the clods are so hard as not to be broken with the heaviest roller. When well-managed, and the season is favourable, it yields good crops of wheat, beans, clover, and oats; but in unkindly seasons for working, and in dry summers, it is very unproductive."

From Portobello Inn to the edge of Wrotham Hill the road runs near the summit-level, crossing several hollows which are about 20 feet deep. These are the upper portions of dry valleys, which commence at the crest of the watershed, about a mile to the S.E., and run northwards nearly parallel to the valley of the Darent, until they wind round towards their lower part to join it. Road-cuttings, made to reduce these irregularities, exhibit the depth and composition of the subsoil, and show it to be from 3 to 5 and 6 feet deep, and to rest on an irregular surface of chalk. It consists of very tenacious clay, with large unabraded flints. The clay is generally reddish brown; but in some places it is mottled with white, yellow, and bright red. The surface is in some places covered with about a foot of sandy loam, with numerous angular flints, more broken than those in the subsoil, which last appear merely as if just detached from the chalk, but are covered with a yellow instead of a white coating. Rounded eocene pebbles are associated more or less with the flints in both deposits. Where the chalk is exposed in the deeper cuttings, its surface is indented with pipes and furrows.

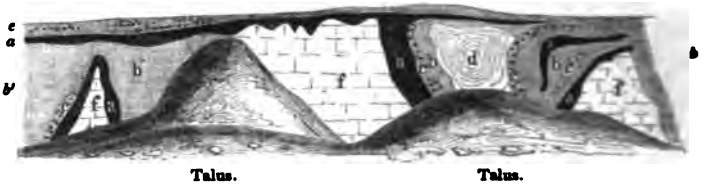
The chalk is covered with this deposit to the very edge of the steep descent of Wrotham Hill. In descending, all traces of it are lost, except as filling pipes, and extending as a thin layer between them, covered by about a foot of cream-coloured calcareous loam, which appears to be *the run of the hill*, the result of atmospheric action, and contains fragments of chalk, angular flints, and rolled eocene pebbles.

At Portobello Inn a by-road branches off to Stanstead, and by the side of this road, about two furlongs from the inn, is a chalk-pit, on the edge of one of the transverse hollows before mentioned as forming the commencement of valleys. This section, which is about 12 feet deep, exhibits the chalk worn into large irregular cavities, 12 to 15 feet wide, covered by dark brown clay, containing numerous unabraded flints, and alternating with light-coloured sandy loam, red and yellow ochraceous sand, and seams of small, rounded eocene pebbles. These alternations pass from a horizontal position on the edge of the cavities to a nearly vertical position within them. They are covered by a thin horizontal deposit of clay, sandy loam, and

flints, with irregular seams of eocene pebbles, as shown in the annexed diagram.

Section near Portobello Inn between Farningham and Wrotham.

N. Scale 12 feet to 1 inch. S.



Talus. Talus.

a. Dark ferruginous clay with flints. *c*. Seams of rounded Eocene pebbles.
b, *b'*. Light-coloured sandy loam. *d*. Red and yellow ochraceous sand.
e. Clay, sandy loam, and Eocene pebbles, in irregular alternations, horizontally stratified; becoming obscure towards the south part of the section. *f*. Chalk.

The materials which fill the cavities in the Portobello section, and form the subsoil in the cuttings on the Wrotham road, have evidently been derived from the wreck of some of the eocene tertiaries; but, if it should be alleged that these cavities and the deposits which they contain belong to the eocene period, I would draw attention to the following facts. None of the eocene strata of this neighbourhood, which are in contact with the chalk, are of the red and yellow colours seen in the specimens now exhibited and obtained from this section. The lowest bed at Woolwich, Bexley, Erith, Crayford, and Dartford is a whitish or greenish sand. Above this is a pebble-bed. The sand generally rests on an even surface of chalk. In the few cases in which it fills cavities in the chalk, the contents are very different from those of the Portobello section. The sands are not only greenish, but the flints have a dark green coating, and the lining of the pipes, instead of being clay, is of an indurated ochreous character. As a contrast to the contents of the Portobello cavities, I exhibit specimens from a pipe in a chalk-pit, a little east of Lullingstone Park. These specimens agree with the characters of the matter filling pipes in the Hampshire basin, where the chalk is there in contact with the lower eocene bed. The Portobello sands and clays, on the contrary, have more of the aspect of those which form the middle portion of the vertical strata of Alum Bay, and which Mr. Prestwich has identified with the Bagshot sands.

Moreover, in the immediate vicinity of Portobello there is an eocene outlier of white sand. In a wood, marked on the Ordnance Map as Knock Mill, but better known on the spot as Gravel-pit Wood, there is a bed of this sand, exposed to the depth of about 12 feet. A reconstructed bed of eocene pebbles, unmixed with angular and subangular flints, and imbedded in a ferruginous base of sand and loam, abuts abruptly against the western edge of the sand, as far as can be judged from the obscure state of the section disturbed by the operations of digging gravel. The contact of the sand with the chalk is not exposed; but the rock must be very near the bottom of the pit. The surface-soil, for some distance through the wood, is

sandy and full of eocene pebbles. This outlier is evidently the source from which the pebbles at the Portobello section were derived; and the flinty cledge, which covers the summits of these high hills, appears to be the source of the broken flints which strew the surface-soil and are imbedded in it, more or less, down to the valley of the Thames, diminishing in quantity with the descent and accumulated in masses at the bottom of the valleys. The distribution of these flints northward along the valleys, and more sparingly south of the chalk-ridge,—the relations of the deposits containing them to the mammalian beds of the valley of the Thames,—and the relations of these, again, to the lower and upper erratics of the northern edge of that valley, will form the subjects of future communications.

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2. *On the* TERTIARY STRATA *of* BELGIUM *and* FRENCH FLANDERS. Part II. *The* LOWER TERTIARIES *of* BELGIUM. By Sir C. LYELL, F.R.S., V.P.G.S.

[Together with Part I., "On the Pliocene, Miocene, and Upper Eocene," read May 5, 1852.]

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§ 1. Introduction and Synoptical Table of the Tertiary formations.
§ 2. Loess or Lehm.
§ 3. Antwerp Crag.—Cetacean remains. Upper, middle, and lower Crag of Antwerp, and comparison of their fossils with the Suffolk Crags and the recent fauna.
§ 4. Sands and Iron-sandstone of Diest.
§ 5. Bolderberg Sands.
§ 6. Limburg Tertiary series.—1. Upper Limburg beds at Rupelmonde, Schelle, and Boom, and their fossils. 2. Tertiary strata in the neighbourhood of Kleyn Spawen, and their threefold division. 3. Micaceous sands of Hénis, Geulem, Klimmen, &c. 4. Relation of the Rupelmonde and Boom Clay to the Upper Limburg beds. 5. The Loess near Kleyn Spawen, and the denudation of the Limburg Tertiary strata. 6. Synoptical tables of Limburg fossils. 7. Nomenclature of the Limburg Tertiary strata, and whether they should be referred to the Upper Eocene or Lower Miocene periods.
§ 7. Middle Eocene Strata of Belgium and French Flanders, or the Nummulitic Eocene.—1. Eocene strata of Cassel, near Dunkirk; Hill of Cassel, Mont Noir, and Boeschepe. 2. Middle Eocene strata of Brussels. Laeken Beds. Dileghem, Jette, and Laeken. Relative position of different species of Nummulites. Brussels Beds, or Upper Nummulitic. Upper Brussels Sands. St. Gilles, Ixelles, Etterbeek, and Dieghem. Fossil Crania and Echinoderms. Fossiliferous Brussels Sands with calcareous concretions. Auderghem, St. Joose-ten-Noode, and Schaerbeek. Nipadites and Honium. Lower Brussels Sands with grotto-stones. Dieghem schistose tripoli. *Cerithium giganteum* bed. 3. Sands with *Nummulites planulatus*. Lower Nummulitic strata near Brussels. Table of Brussels and Cassel Middle Eocene fossils. Analogy of the Belgian, French, and English Eocene strata. Middle Eocene strata at Mons and Mont Panisel. Renaix, Craye, and Audenaerde. Courtray. Ghent. Mons-en-Pevelle.
§ 8. London Clay proper of Cassel and Lille.
§ 9. Plastic clay, sand, and lignite of Carvin near Lille, Jauche, Huppaye, &c.
§ 10. Glauconite of Tournay, Angres, Folx-les-Caves, Orp-le-grand, Lincent, &c.
§ 11. Marls and Glauconite of Heers.

[PLATES XVII. to XX.]

§ 1. THE following observations are the result of a visit made in the summer of last year (1851) to parts of French Flanders and Belgium, undertaken with a view of comparing the tertiary strata of that part of the continent with those of England.

I shall first describe what I saw of the newest deposits, and then proceed to consider the others in a descending series until I arrive at strata which repose immediately on the chalk of Maestricht.

For convenience of reference, and in explanation of the nomenclature adopted, a synoptical table of formations (Table I.) is annexed.

§ 2. *Loess or Lehm* (A. Table I.). *Limon de Hesbaye* of M. Dumont.

The southern half of Belgium is overspread almost everywhere by a continuous deposit of clayey loam, resembling in colour and composition the well-known "loess" of the Rhine. This loam has been called "Hesbayan mud" by M. Dumont, because it abounds in the ancient province of Hesbaye, which includes, among other areas, the country between Liege and Waremme and between Liege and Tongres. It presents generally the same uniformity of aspect and composition, and the same absence of stratification which characterize it on the Rhine between Cologne and Basle. In Belgium, however, land and freshwater shells are much more rare, and the only spot where I met with any was at the village of Neerepen, between Tongres and Hasselt (see Map, Pl. XVII. fig. 4), where they had been previously remarked by M. Bosquet. Here I found abundantly the *Succinea oblonga*, so common in the Rhenish loess, and *Helix hispida*. The tusks of a fossil Elephant were also obtained here by M. Bosquet. The only shells which I heard of as having been detected elsewhere in the Belgian loess consisted of recent species, all of terrestrial or fluviatile genera.

The thickness of the "Hesbayan mud" is variable, usually ranging from 10 to 30 feet. It is seen capping some of the highest hills or table-lands near Brussels; as for example, that above the villages of Jette and Dileghem, west of Laeken (see Map, Pl. XVII. fig. 3), at the height of about 300 feet above the sea. At the base of the loess, or between it and the older rocks, there occur very generally one or more beds of gravel. In some cases, as I shall hereafter have to point out, where it rests on unconsolidated tertiary sands and loams, there is such an intermixture of the newer and older deposits, owing to denudation and redeposition (the fossils washed out of the older beds often remaining entire), that it is most difficult to draw a line of separation.

The homogeneous character of the loess throughout the hydrographical basin of the Rhine always disposed me to refer its origin to some common source, such as a great river which had brought down for ages the same kind of sediment, and spread it over a large area, while that area was slowly subsiding. I also supposed that the same region had been subsequently re-elevated and denuded, so that most

Table I.

Synoptical Table of Tertiary Formations of Belgium and French Flanders.*

	Names adopted in this Memoir.	Nomenclature used by M. Dumont in his Map of Belgium.	British equivalents.	French equivalents.	Periods.
A.....	Loess and Alluvium	Limon Hesbayen	Brick-earth, drift, &c.	Alluvions and Loess.	Post-pliocene and Pleistocene.
B. 1. ..	Antwerp Crag	Système Scaldesien.	Red and coralline Crags of Suffolk.	Crag de Carentan, Normandie.	Pliocene.
B. 2. ..	Sands of Diest.....	S. Diestien.			
C.....	Bolderberg Sands	S. Bolderien....	Wanting.....	Faluns de la Loire	Miocene.
D. 1. ..	Upper Limburg Beds, or Rupelmonde Clay.	S. Rupelien.	Upper freshwater, and upper marine of the Isle of Wight.	Calcaire de la Beauce.	Upper Eocene (Lower Miocene of many authors).
D. 2. ..	Middle Limburg, or Fluvio-marine.	S. Tongrien supérieur.		Sables et Grès de Fontainebleau. Marnes à Ostrea cyathula.	
D. 3. ..	Lower Limburg	S. Tongrien inférieur.		Marnes supérieurs au gypse.	
E. 1. ..	Laeken Beds, or Upper Nummulitic (*Nummulites variolarius*).	S. Laekenien....	Barton Clay	Sables moyens ou Grès de Beauchamp.	Middle (or Nummulitic) Eocene.
E. 2. ..	Brussels Beds, or Middle Nummulitic (*Nummulites lævigatus*).	S. Bruxellien....	Bagshot and Bracklesham Beds.	Calcaire grossier.	
E. 3. ..	Lower Nummulitic Beds (*Nummulites planulatus*).	S. Paniselien?, and S. Ypresien, étage supérieur.		Sables Soissonnais, partie supérieure.	
F. 1. ..	London Clay	S. Ypresien, étage inférieur.	London Clay proper.	Wanting.....	Lower Eocene.
F. 2. ..	Plastic Clay and Sands ..	S. Landenien supérieur.	Lower London Tertiaries.	Lignite Soissonnais.	
G.	Glauconite and Tufeau of Lincent.	S. Landenien inférieur.	Wanting.		Intermediate between Eocene and Cretaceous.
H.	Marls and Glauconite of Heers.	S. Héersien	Wanting.		
I.....	Maestricht Chalk.....	Calcaire de Maestricht.	Wanting.		Cretaceous.

* In Appendix, Nos. I. and II., at the end of this paper, will be found two Tables by M. Dumont, the first published in 1851, and the second previously unpublished, in which that distinguished geologist explains his views respecting the classification of the Belgian tertiary strata, and their synchronism with those of England and France.

of the valleys and inequalities, previously existing before they were filled up with loess, were partially or entirely re-excavated, and some new ones formed*.

Having since the publication of these views had an opportunity of examining the loess of the basin of the Mississippi,—a formation singularly identical in mineral characters and in the genera of its included shells,—my conclusions respecting the nature of the European loess and its mode of origin have been confirmed†.

The phænomena can be best explained, both in Europe and North America, by supposing a gradual subsidence of dry land to the extent of several hundred feet during the deposition of the fluviatile mud, and an equally gradual upheaval of the same tract during the period when extensive denudation was effected. In the same manner as the southern and seaward termination of the loess is somewhat abrupt in Louisiana, where it bounds the delta of the Mississippi, so the corresponding mass of upraised freshwater mud in Belgium ceases somewhat suddenly along a well-marked line, which has been traced out by MM. d'Omalius d'Halloy, Dumont, and others, running east and west nearly along the 51st parallel of latitude, by Cologne, Juliers, Louvain, Audenaerde, and Courtray in Belgium, to Cassel, near Dunkirk, in France. Whether this line indicates the original extent of a fluviatile formation, or whether it was produced by the denudation of a deposit once stretching farther north, I am unable to decide. Its absence beyond the line alluded to is of great importance to a geologist who is examining the tertiary strata of the low countries bordering the sea, for it allows them to appear at the surface, except where they are concealed by fine sand, much resembling the dunes on the coast. Everywhere to the south of lat. 51° the loess greatly impedes the geological observer, not only by its continuity and thickness, but also by producing a soil so favourable to agriculture, that sand-pits, excavations for clay, or quarries of building-stone, paving-stone, limestone, and other materials, if opened, are almost always filled up immediately, in order that no space may be lost to the farmer. The geologist, therefore, in a country where natural sections are rare, is often reduced to such artificial ones as happen to be exhibited during the workings of a single year.

In regard to the relative ages of the loess and the northern drift, with its erratics, the only positive information which I obtained during this tour was on crossing the Meuse from Maestricht to the right bank of that river, opposite the city. Here, in company with M. Van Rymsdyck, I observed that the sands of the Limburg tertiary series were covered by a bed of quartzose gravel with erratics, and this again by loess 30 feet thick. The locality alluded to is the table-land of Rassburg, near Geulem, which is about 300 feet above the Meuse, and about 450 feet above the level of the sea. The erratics are some of them very angular, and more than 2 feet in diameter, consisting of quartzose slate, similar to that of the Ardennes, from which they are believed to have been transported.

* See Proceed. Geol. Soc. vol. ii. p. 83; and Edinb. New Phil. Journ. July 1833.

† Second Visit to the United States, vol. ii. p. 294; and *ibid.* chap. xxxiv.

Such an instance of the superposition of loess to a certain class of erratics, will not justify the conclusion that the origin of the loess generally was of later date than the northern drift. I should rather infer from the fact here mentioned, that the transportation by ice of large blocks was still going on when a part of the Belgian loess was deposited;—in other words, the glacial epoch coincided, in part at least, with the epoch of the formation of the loess. I conceive that the more intense cold had passed away, or receded northwards, before the principal mass of the loess was thrown down.

§ 3. *Antwerp Crag* (B. 1. Table I. p. 279). *Système Scaldesien*, Dumont, 1851. *Système Campinien*, Dumont, 1839.

The excellent and well-known work of M. Nyst, published in 1843, on the shells and corals of the tertiary formation of Belgium, has made every geologist familiar with the fact, that a large number of species of fossils are common to the Suffolk Crag and to strata in the neighbourhood of Antwerp. M. Nyst has taken frequent occasion to acknowledge that a considerable proportion of these Antwerp fossils were communicated to him by M. Norbert de Wael, and I was fortunate enough to obtain the friendly cooperation of that excellent observer and indefatigable collector during my visit to Antwerp. He placed most liberally at my disposal, and for my use when writing this memoir, not only a part of his collection, which Mr. Searles Wood has compared with fossils from the English Crag, but also his MS. lists of organic remains, and his notes on the geology of the localities most fertile in fossils, several of which we visited together.

There are no natural sections to be seen in the flat country around Antwerp, but excavations to the depth of a few feet in the town and its suburbs are continually exposing to view beds of sand and shells. One of these I found in progress on my arrival on the eastern side of the city, in the Zoological Gardens. Here they were digging ponds 20 feet deep, from which yellow sand had been thrown out, containing *Fusus contrarius*, *Voluta Lamberti*, *Pecten maximus*, *Pecten opercularis*, *Ostrea edulis*, *Cyprina tumida*, *Astarte borealis*, and many others, which I at once recognized as among the most common shells of the Suffolk Crag. I also observed that they had met with many large vertebræ of Whales in a perfect and unrolled state. I obtained one of these, measuring 6½ inches in its longitudinal, and as much in its transverse diameter, and Prof. Owen has pronounced it to be the lumbar vertebra of a *Balænoptera*. These cetacean relics, which are very common in the district, were associated with large Sharks' teeth, of the genus *Carcharodon*.

At Steuvenberg (a name which implies a hill of sand), east of the fortifications and north of the Zoological Gardens, I found excavations for sand, in which many of the same shells were seen, with others which will be alluded to in the sequel.

On the northern glacis of the fortifications I saw that a very different sand had been recently thrown up from a depth of 20 feet, consisting of a dark green and almost black glauconite. This is called "crag noir," or glauconiferous crag. It contains many of the

same species of shells which I had seen in the yellow crag, but mixed with some others peculiar to it. The *Pectunculus variabilis*, Sow., is by far the most abundant shell.

On the glacis, at a higher level, greyish sand with green grains appears, which M. de Wael calls "crag gris or moyen," and which he regards as of intermediate age between the "yellow" and "black" crags already alluded to.

About three miles south of Antwerp, between the villages of Berchem and Vieux Dieu, I came accidentally upon a new excavation in a garden which exhibited the crag under a different aspect. At the top were mottled, red, and whitish sands, 12 feet thick, the lowest layers containing many small quartz-pebbles, under which was an argillaceous sand with numerous ball-like concretions of clay-stone in which were casts of large Bivalves, chiefly of *Pectunculus* (*P. variabilis*?), and others apparently referable to a large *Mactra* and to a *Venus*, each of which had served as the nucleus of a nodule. The vertebræ of Fish and teeth of Sharks were numerous. Among the latter one large tooth belongs to *Oxyrhina trigonodon*, Agassiz, which I also obtained from the clay of Rupelmonde. A second species comes nearest to *Carcharodon Escheri*, Agassiz, and may perhaps be identical, although less oblique than the specimen figured by Agassiz, who procured his fossil from the Molasse of Switzerland. I found mixed with these many unrolled bones of Whales of a different species from that which I had seen in the yellow crag at Antwerp. Prof. Owen was able from my specimens to refer these bones to the caudal and cervical vertebræ of some species of Cuvier's extinct genus *Ziphius*. The caudal vertebra is 3¼ inches in its larger diameter. I was told of many other places where cetacean relics occur near Antwerp; and M. Van Beneden, in his memoir on the subject, states that it is scarcely possible to penetrate a few feet beneath the soil at the villages of Wommelghem and Deurne without encountering cetacean remains which have formed parts of entire skeletons buried on the spot. Some of these fossils, dug up at Antwerp within the walls of the city, were figured by Cuvier, and referred to his genus *Ziphius**. At Niel, near Antwerp, M. Van Beneden met with an ear-bone, which he ascribes to the genus Rorqual or *Balænoptera*†.

We may therefore regard such cetaceans as truly characteristic of the Antwerp Crag; a fact strongly confirmatory of the opinion entertained by Mr. Searles Wood and Mr. Charlesworth, and advocated by myself in 1851‡, that the cetacean relics met with in the Crag of Suffolk, much worn and rolled, have not been derived from the London clay, as some had contended, but were more probably washed out of denuded beds of crag; it being clear that strata in Belgium of the same age as the Suffolk Crag were accumulated in a sea inhabited by numerous Whales belonging to several genera.

The Crag of the neighbourhood of Antwerp, like that of Suffolk, is very variable in composition, and often entirely devoid of fossils.

* Cuv. Oss. Foss. pl. 27. figs. 7 & 8.
† Bullet. Acad. Roy. de Belgique, 1846. vol. xiii. pt. 1. p. 257.
‡ Manual of Geology, 3rd edit. p. 166.

In some districts near the sea it is concealed beneath a superficial covering of stiff tenacious clay of fluviatile origin, provincially called "Polders," full of recent land and freshwater shells, and resembling the dark-coloured clay now deposited by the Scheldt during its annual inundations.

In the absence, therefore, of natural sections, it is not always possible to obtain good proofs of the relative position of particular masses of sands and clay occurring here and there at the surface, although the same have appeared to MM. Nyst and De Wael to contain internal or palæontological evidence of being of different ages. This conclusion has been deduced principally from the greater or less agreement of the shells with living species, especially with those now existing in the neighbouring sea;—a subject to which I shall refer more fully in the sequel.

1. *Yellow Crag. Upper Antwerp Crag.*

At Calloo, one of the spots most fertile in fossil shells, situated two leagues N.W. of Antwerp (see Map, Pl. XVII. fig. 1) on the left bank of the Scheldt, M. de Wael observed the following section of strata referred by him to the upper or yellow crag:—

	Thickness. feet.	inches.
1. Mud or "polder"	1	6
2. Clay and loam	3	6
3. Yellow sand	1	0
4. Yellow shelly sand	5	0
	11	0

The following is a list of shells from this spot in the collection of M. de Wael, to which, with the assistance of Messrs. Searles Wood and Morris, I have added two columns showing the proportion of Antwerp species common to the Red and Coralline Crag of Suffolk, and another column to indicate which species are still living. In identifying shells, enumerated by M. de Wael in his MS. lists, of which I do not possess specimens from Calloo, we have availed ourselves of M. Nyst's figures and descriptions; but, if any doubt existed as to the species meant, it has been omitted altogether.

The column specifying the rarity or abundance of the shells is furnished by M. de Wael, and may be useful in determining the depth of the sea in which the strata were formed. Where there is a blank in that column, the species are neither common nor rare, although some of them may be very rare in collections owing to their fragility.

Table II.

Table of Shells from the Upper or Yellow Crag, collected by M. Norbert de Wael at Calloo, *near Antwerp.*

		Cor.	Red.	Recent.
1. Solen ensis, *Linn.*	.....	•	•	•?
? *Ensis complanatus*, Sow.				
2. Solecurtus candidus?, *Ren.*	very rare.	•	.....	•?
3. Glycimeris angusta, *Nyst*	rare.	•	•	
4. Mya arenaria, *Linn.*	very rare.	.....	•	•
5. Corbulomya complanata, *Sow.*	rare.	.....	•	
6. Corbula gibba, *Oliv.*	common.	•	•	•
C. planulata, Nyst.				
7. Lutraria elliptica, *Lamk.*	very rare.	•	•	•
8. Mactra solida, *Linn.*	rare.	.....	•	•
9. —— arcuata, *Sow.*	rare.	•	•	
10. —— inequilateralis, *Nyst*	very common.	.....	•	
11. Erycina depressa, *Nyst*	.....	•	•	
12. Ligula alba, *W. Wood*	.....	•	•	•
13. Petricola laminosa, *Sow.*	.....	•	•	
14. Psammobia Dumontii, *Nyst*	.....	•	.....	•
P. vespertina?, Turton.				
15. Tellina Benedenii, *Nyst*	common.	.....	•	
16. —— obliqua, *Sow.*	rare.	•	•	
17. —— crassa, *Pennant*	rare.	•	•	•
T. obtusa, Sow.				
18. —— calcarea, *Gmel.*	common.	.....	•	•
T. ovata, Nyst.				
19. Tellina lupinoides, *Nyst*	.....	•	•	•
T. articulata, Nyst.				
Lucinopsis Lajonkairii, Payr.				
20. Donax striatella, *Brocc.*	.....	•	•	•
Tellina donacina, Linn.				
21. Lucina astarte, *Nyst*	.....	•	•	
22. —— radula, *Lamk.*	rare.	•	•	•
L. antiquata, Sow.				
23. —— digitaria, *Linn.*	.....	•	•	•
L. curviradiata, Nyst.				
24. Cyprina tumida, *Nyst*	.....	•	•	
C. rustica, Sow.				
25. Astarte borealis, *Linn.*	very common.	.....	.....	•
A. plana, Sow.				
26. —— Basterotii, *Lajonk.*	very rare.	•	•	
27. Venus striatella, *Nyst*	very rare.			
28. Artemis exoleta, *Linn.*	common.	•	•	•
29. Cardium Parkinsoni, *Sow.*	.....	.....	•	
30. —— oblongum, *Nyst*	.....	•		
31. —— edule, *var. Linn.*	common.	•	•	•
C. edulinum, Sow.				
32. Cardita scalaris, *Sow.*	rare.	•	•	
33. Nucula lævigata, *Sow.*	common.	•	•	
34. Pectunculus glycimeris, *Linn.*	.....	•	•	•
P. variabilis, Sow.				

TABLE II. (continued).

		Cor.	Red.	Recent.
35. Pecten maximus, *Linn.* ..... *P. complanatus*, Sow.	common.	•	•	•
36. —— opercularis, *Linn.* ..... *P. Sowerbyi*, Nyst.	very common.	•	•	•
37. —— dubius, *Brocchi* ..... *P. radians*, Nyst.	.....	•	•	
38. —— Pusio, *Pennant* ..... *P. striatus*, Sow.	rare.	•	•	•
39. Anomia ephippium, *Linn.*	common.	•	.....	•
40. Ostrea edulis, *Linn.*	common.	•	•	•
41. Emarginula fissura, *Linn.*	very rare.	•	•	•
42. —— crassa, *Sow.*	very rare.	•	•	•
43. Fissurella græca, *Lamk.*	very rare.	•	•	•
44. Calyptræa sinensis, *Desh.* ..... *C. recta*, Sow.	rare.	•	•	•
45. Trochus cinerarius, *Linn.* ..... *T. octosulcatus*, Nyst.	rare.	.....	•	•
46. Littorina suboperta, *Sow.*	rare.	.....	•	
47. Turritella incrassata, *Sow.* (recent, Mediterranean) ..... *T. triplicata*, Brocc.	very rare.	•	•	•
48. Melania terebellata, *Nyst* ..... *Paludestrina terebellata*, S. Wood.	.....	.....	•	
49. Tornatella (Actæon) Noæ, *Nyst.* ...	very rare.	.....	•	
50. Natica crassa, *Nyst*	common.	•		
51. —— Sowerbyi, *Nyst*	rare.	.....	•	
52. Bulla cylindracea, *Pennant* ..... *B. convoluta*, Nyst.	rare.	•	•	•
53. Fusus contrarius, *Gmel.*	.....	.....	•	•
54. —— corneus, *Sow.*	.....	•	•	•
55. Pleurotoma turricula, *Brocch.*	.....	.....	•	
56. —— mitrula, *Sow.*	.....	•	•	•?
57. Purpura tetragona, *Sow.* ..... *Murex alveolatus*, Sow.	very rare.	.....	•	
58. Purpura lapillus, *Linn.* ..... *Murex incrassatus*, Nyst.	rare.	.....	•	•
59. Rostellaria pes pelicani, *Linn.*	rare.	•	•	•
60. Buccinum (Nassa) reticosum, *Sow.* *B. elongatum*, Sow. *B. rugosum*, Sow. *B. reticosum*, Sow.	common.	.....	•	
61. —— labiosum, *Sow.*	rare.	•	•	
62. —— propinquum, *Sow.*	rare.	.....	•	
63. —— undatum, *Linn.* ..... *B. tenerum*, Sow.	rare.	•	•	•
64. Terebra inversa, *Nyst*	rare.	•	•	
65. Voluta Lamberti, *Sow.*	rare.	•	•	
66. Cypræa europæa, *Mont.* ..... *C. coccinelloides*, Sow. *C. coccinella*, Nyst.	rare.	•	•	•
		46	59	37

Three shells of the above list—*Astarte Basterotii, Turritella incrassata*, and *Purpura tetragona*—are so rare at Calloo, and so much worn when they occur, that they are believed by M. de Wael to have been derived from an older bed of the Middle or Grey Crag. A single rolled valve of *Astarte corbuloides* is supposed, in like manner, to have been washed out of an older bed. But the admission or omission of these fossils will not be found to affect the following conclusions, which may be drawn from the whole list:—

1st. The result which is most striking, is that out of 66 shells no less than 64 are common to the Suffolk Crag; occurring either in the red or coralline crags. There can, therefore, be no doubt of the contemporaneity of the Upper Crag of Antwerp with the English or Suffolk Crag.

2ndly. Fifty-nine species out of 66 are common to the red, and 45 to the coralline crag, so that the resemblance to the red or upper crag is greatest.

3rdly. Thirty-seven out of 66, or more than half the shells (55 per cent.), have been identified with living species; and the analogy of these with the fauna of the Northern Seas is very great, as in the case of the Crag of Suffolk.

The upper or yellow sand is usually unconsolidated, and for the most part without shells; often micaceous, and occasionally with a slight mixture of argillaceous or calcareous matter. At Steuvenberg, a locality before alluded to, which I visited, in the eastern suburbs of Antwerp, some beds were formerly worked which were so calcareous as to be used for roads, and even burnt for lime; the carbonate of lime appearing to be derived from the decomposition of shells. From this spot M. de Wael has in the course of many years obtained the following shells, which, like those of Calloo, have been compared with British Crag species by Mr. Wood.

Table III.*

Fossil Shells from the Upper or Yellow Crag at Steuvenberg, *in the Eastern suburbs of Antwerp, collected by M. Norbert de Wael.*

		Cor.	Red.	Recent.
1. Solen ensis, *Linn.*	.....	•	•	•
2. Solecurtus candidus, *Ren.*	very rare.	•	.....	•
3. Glycimeris angusta, *Nyst*	rare.	•	•	
4. Corbula gibba, *Oliv.*	.....	•	•	•
5. Corbulomya complanata, *Sow.*	very common.	.....	•	
6. Mactra arcuata, *Sow.*	very rare.	•	•	
7. —— striata, *Nyst* ..... *M. dubia*, Sow.	.....	•?	•?	•
8. Erycina ambigua, *Nyst* ..... *Kellia ambigua*, S. Wood.	rare.	•	•	

* The synonyms given in Table II. are not repeated here.

TABLE III. (continued).

		Cor.	Red.	Recent.
9. Erycina faba, *Nyst* ..... *Montacuta bidentata*, Montag.	.....	•	•	•
10. Petricola laminosa, *Sow.*	rare.	•	•	•
11. Psammobia Dumontii, *Nyst*..... *P. Feroensis*, Lamk.	rare.	•	.....	•
12. Tellina Benedenii, *Nyst*	common.	.....	•	
13. —— calcarea, *Gmel*.....	rare.	.....	•	•
14. —— solidula?, *Pennant*	rare.	.....	.....	•?
15. Donax striatella, *Brocc.*	.....	•	.....	•
16. Lucina astartea, *Nyst*	.....	•	•	
17. —— radula, *Lamk.*	rare.	•	•	•
18. Diplodonta dilatata, *Phil*.....	rare.	•	•	•
19. Astarte borealis, *Linn.*	.....	.....	.....	•
20. —— Basterotii, *Lajonk.*	rare.	•	•	
21. Venus striatella, *Nyst*				
22. Artemis exoleta, *Linn.*	.....	•	•	•
23. Cardium edule var., *Sow.*	common.	•	•	•
24. Cardita scalaris, *Sow.*	rare.	•		
25. Nucula depressa, *Nyst*.....	rare.	•		
26. —— lævigata, *Sow.*	.....	•	•	
27. Pectunculus glycimeris, *Linn.*..... *P. variabilis*, Sow.	rare.	•	•	•
28. Mytilus antiquorum, *Sow.*	rare.	.....	•	•
29. Pecten opercularis, *Linn*.....	rare.	•	•	•
30. Anomia ephippium, *Linn.*	.....	•	.....	•
31. Ostrea edulis, *Linn.*.....	rare.	•	•	•
32. Lingula Dumortieri, *Nyst*	common.	•		
33. Emarginula crassa, *Sow.*	very rare.	•	•	•
34. Calyptræa sinensis, *Linn*.....	rare.	•	•	•
35. Trochus papillosus, *Da Costa* ..... *T. similis*, Sow.	rare.	.....	•	•
36. —— trigonostomus, *Basterot* ..... *Adeorbis subcarinatus*, Wood.....	.....	•	•	•
37. Natica crassa, *Nyst*	.....	•		
38. Scalaria frondicula, *Wood*.....	rare.	•	•	
39. —— subulata, *Sow.*	rare.	•		
40. Turritella incrassata, *Sow*.....	rare.	•	•	•
41. Eulima subulata, *Risso*.....	.....	•	.....	•
42. Tornatella conoides, *Nyst*	common.	•	.....	•
43. Bulla cylindracea, *Pennant*	common.	•	•	•
44. Auricula pyramidalis, *Sow.* ..... *Conovulus*, Wood.	rare.	.....	•	
45. Rostellaria pes pelicani, *Linn.*.....	rare.	•	•	•
46. Fusus contrarius, *Sow*.....	.....	.....	•	•
47. Buccinum reticosum, *Sow.*	rare.	.....	•	
48. —— labiosum, *Sow*.....	.....	•	•	
49. —— propinquum, *Sow.*	.....	.....	•	
50. Terebra inversa, *Nyst*	rare.	•	•	
51. Voluta Lamberti, *Sow*.....	rare.	•	•	
52. Cypræa Europæa, *Gmel.*	very rare.	•	•	•
		39	37	31

In this list of 52 species it will be seen that no less than 49 species, or all but 3, occur in the Suffolk Crags; 37 in the red, and 39 in the Coralline crag. Thirty-one of the species are recent (60 per cent.), a larger proportion than at Calloo.

2. *Middle or Grey Crag.*—Next in age, in the opinion of M. de Wael, is the grey crag before mentioned, called *Crag gris*, or *Crag moyen*. It has afforded the largest number of fossil shells, as will be seen by the following list.

Table IV.

Fossil Shells from the Middle Crag (Crag moyen *or* Crag gris), *collected by M. Norbert de Wael.*

	Cor.	Red.	Recent.
1. Corbula gibba, *Oliv.*	•	•	•
2. —— (Poromya) granulata, *Nyst*	•	.....	•
3. Mactra striata, *Nyst*	•	•	
4. Syndosmya prismatica, *W. Wood* ..... *Amphidesma prismaticum*, Montag. *Ligula donaciformis*, Nyst.	•	.....	•
5. Tellina obliqua, *Sow.*	•	•	
6. —— lupinoides, *Nyst*	•	•	•
7. —— Benedenii, *Nyst*	.....	•	
8. Lucina radula, *Montag.*	•	•	•
9. —— digitaria, *Linn.*	•	•	•
10. —— astartea, *Nyst*	•	•	
11. Axinus (Cryptodon) sinuosus, *Donov.*	•	.....	•
12. Diplodonta dilatata, *Phil.*	•	•	
13. Cyprina rustica, *Sow.*	•	•	
14. —— islandica, *Linn.*	•	•	•
15. Astarte mutabilis, *Wood* ..... *A. planata*, Nyst (non Sow.).	•	•	
16. —— borealis, *Linn.* ..... *A. plana*, Sow.	.....	.....	•
17. —— Basterotii, *Lajonk.*	•	•	
18. —— Omalii, *Lajonk.*	•	•	
19. —— Burtini, *Lajonk.*	•	•	
20. —— obliquata, *Sow.*	.....	•	
21. —— gracilis, *Goldf.*	•	•	
22. —— corbuloides, *Nyst*			
23. —— sulcata, *Mont.*	.....	•	•
24. Venus spadicea, *Ren.* ..... *V. ovata*, Mont.	•	•	•
25. —— rudis, *Poli.*	•	•	•
26. —— imbricata, *Sow.* ..... *Astarte imbricata*, Sow.	•	•	
27. —— minima, *Mont.*	•	•	•
28. —— chione, var., *Linn.* ..... *V. chionoides*, Nyst.	•	.....	•
29. —— turgida, *Sow.* ..... *V. multilamellata*, Nyst. *V. casina*, Linn.	•	•	•?

TABLE IV. (continued).

	Cor.	Red.	Recent.
30. Artemis exoleta, *Linn.*	*	*	*
31. Cardium echinatum, var.?, *Linn.*	.....	*	*
32. —— edule, var., *Linn.*	*	*	*
33. Isocardia cor, *Linn.*	*	*	*
34. Cardita chamæformis, *Sow.*	*	*	
35. —— orbicularis, *Sow.*	*	*	
36. —— scalaris, *Sow.*	*	*	
37. —— squamulosa, *Nyst*	*	*	
38. Nucula depressa, *Nyst*	*		
Leda semistriata, S. Wood.			
39. Limopsis aurita, *Brocchi*	*		
Trigonocœlia sublævigata, Nyst.			
40. Pectunculus glycimeris, *Linn.*	*	*	*
41. Lima subauriculata, *Montag.*	*	.....	*
42. Pecten maximus, *Linn.*	*	*	*
P. grandis, Sow.			
43. —— Westendorpianus, *Nyst*			
44. —— opercularis, *Linn.*	*	*	*
45. —— dubius, *Brocc.*	*	*	
P. radians, Nyst.			
46. —— pusio, *Pennant*	*	*	*
47. —— Gerardii, *Nyst*	*		
48. —— tigerinus, *Müll.*	*	*	*
49. Anomia ephippium, *Linn.*	*	.....	*
50. Ostrea princeps, *S. Wood*	*	*	
51. —— edulis, *Linn.*	*	*	*
52. Terebratula grandis, *Blum.*	*	*	
T. gigantea, Schloth.			
T. variabilis, Sow.			
53. Lingula Dumortieri, *Nyst*	*		
54. Dentalium entale, *Linn.*	*	*	*
D. semiclausum, Nyst.			
D. costatum?, Sow.			
55. Emarginula fissura, *Linn.*	*	*	*
56. —— crassa, *Sow.*	*	*	*
57. Fissurella græca, *Linn.*	*	*	*
58. Calyptræa sinensis, *Linn.*	*	*	*
59. Pileopsis ungarica, *Linn.*	*	*	*
60. Trochus papillosus, *Da Costa*	.....	*	*
T. granosus, Nyst.			
T. similis, Sow.			
61. —— zizyphinus, *Linn.*	*	*	*
T. lævigatus, Sow.			
T. Sedgwickii, Sow.			
62. —— Kickxii, *Nyst*	*	*	
63. —— cinerarius, *Linn.*	.....	*	*
64. Solarium turbinoides, *Nyst*	*		
Margarita maculata, S. Wood.			
65. Littorina suboperta, *Sow.*	.....	*	
66. Scalaria frondicula, *S. Wood*	*	*	

TABLE IV. (continued).

	Cor.	Red.	Recent.
67. Turritella incrassata, *Sow.*	•	•	
68. Natica cirriformis, *Sow.*	•		
69. —— crassa, *Nyst*	•		
70. —— hemiclausa, *Nyst*	.....	•	
71. —— clausa, *Brod. & Sow.*	.....	•	•
72. —— Sowerbyi, *Nyst*	.....	•	
73. Bulla lignaria, *Linn.*	•	•	•
74. —— cylindracea, *Penn.*	•	•	•
75. Cancellaria umbilicaris, *Brocc.*			
76. —— coronata, *Scacchi*	•	•	
C. varicosa, Phil.			
77. Fusus alveolatus, *Sow.*	•	•	
78. —— contrarius, *Gmel.*	.....	•	•
79. —— clathratus?, *Lamk.*			
80. —— corneus, *Sow.*	•	•	•
81. —— echinatus, *Sow.*	.....	•	•
Murex muricatus, Mont.			
82. Pleurotoma intorta, *Brocc.*	.....	•	
83. —— turricula, *Brocc.*	.....	•	
84. Rostellaria pes pelicani, *Linn.*	•	•	•
85. Buccinum Dalei, *Sow.*	•	•	•
B. crassum, Nyst.			
86. —— flexuosum?, *Brocc.*	.....	•	
87. —— elegans, *Sow.*	.....	•	
88. —— reticosum, *Sow.*	.....	•	
89. —— undatum, *Linn.*	•	•	•
B. tenerum, Sow.			
90. —— propinquum, *Sow.*	.....	•	
91. —— labiosum, *Sow.*	•	•	
92. Cassidaria bicatenata, *Sow.*	•	•	
93. Ringicula buccinea, *Brocc.*	•	•	
94. Cypræa europæa, *Gmel.*	•	•	•
	71	76	46

In the above list of 94 species it will be observed, by reference to the first two columns, that all but four of them are common to the Crag of Suffolk, and that 76 occur in the red crag, and 71 in the older or coralline crag. The proportion of recent species, as given in the third column, is 46, or nearly half of the whole, rather a smaller proportion than in the yellow crag, as shown in Tables II. and III.

3. *Glauconiferous Crag* or *Crag Noir. Lower Antwerp Crag.*—It has hitherto been the opinion of the Belgian geologists that the glauconiferous crag, or the dark green shelly sand of Antwerp, was considerably older than the two preceding groups, departing much farther in its fauna from that of the existing seas, and containing many shells common to older tertiary formations.

When I submitted a small collection of specimens which I obtained myself from this bed, consisting of the more abundant and therefore

most characteristic fossils, to Mr. Searles Wood, on my return from Belgium, he came to a different conclusion, which induced me to examine more critically the evidence furnished to me on this point by M. de Wael.

In the following Table I have enumerated all the species named in M. de Wael's MS. lists which could be distinctly recognized, whether by the aid of specimens in my own collection (chiefly presented to me by M. de Wael), or by the figures of M. Nyst, and have only omitted a small number respecting which M. de Wael has himself expressed doubts. The results will be given at the conclusion of the annexed Table.

TABLE V.

Shells from the Glauconiferous or Lower Crag of Antwerp (Crag noir), *in the collection of M. Norbert de Wael.*

		Cor.	Red.	Recent.
1. Corbula gibba, *Oliv.*	common.	*	*	*
2. —— (Poromya) granulata, *Nyst*	very rare.	*	.....	*
3. —— Waelii, *Nyst*. *Neæra costellata*?, Forbes and Hanley.	rare.	.....	.....	*?
4. Mactra striata, *Nyst*. *M. elliptica*, Brown.	common.	*	*	*
5. Erycina ambigua, *Nyst*	rare.	*	*	
6. Syndosmya prismatica, *W. Wood*	common.	*	.....	*
7. Saxicava arctica, *Linn.*	common.	*	*	*
8. Donax fragilis, *Nyst*	very rare.			
9. Lucina radula, *Montag.*	common.	*	*	*
10. Diplodonta dilatata, *Phil.*	common.	*	*	*
11. Astarte radiata, *Nyst*. *A. gracilis*?, Münst.	common.	*		
12. —— minuta, *Nyst*	rare.			
13. —— Omalii, *Lajonk.*	very rare.	*	*	
14. Venus multilamellata, *Sow.* *V. turgida*, Sow.	common.	*	*	*?
15. —— incrassata, *Sow.*	rare.			
16. Cardium turgidum, *Brander*	rare.			
17. Isocardia lunulata, *Nyst*	rare.	*	*	*?
18. Cardita squamulosa, *Nyst*	rare.	*	*	
19. —— corbis, *Phil.*	very rare.	*	*	*
20. —— orbicularis, *Sow.*	rare.	*	*	
21. Nucula depressa, *Nyst*	.....	*		
22. —— Philippiana, *Nyst*. *N. tenuis*, Phil. *N. pygmæa*, Goldf.	common.	*	.....	*
23. —— Westendorpii, *Nyst*	rare.			
24. —— Hasendonckii, *Nyst*	rare.			
25. Limopsis aurita, *Brocc.* *L. sublævigata*, Nyst.	.....	*		
26. —— decussata, *Nyst*. *Trigonocœlia pygmæa*, Phil.	very rare.	*		

TABLE V. (continued).

		Cor.	Med.	Recent.
27. Pectunculus glycimeris, *Lamk*.....	very common.	•	•	•
28. Arca diluvii, *Lamk.*	very rare.	.....	.....	•
29. —— pusilla, *Nyst*.....	very rare.	•	.....	•
30. Mytilus sericeus, *Goldf*.....	very rare.	•		
31. Pecten Lamalii, *Nyst* ..... *P. Brusi*, Payr.	common.	•	.....	•
32. —— maximus, *Linn.* ..... *P. jacobæus*, Lamk.	very rare.	•	•	•
33. Ostrea cochlear?, *Poli*	very rare.	.....	.....	•?
34. Dentalium costatum, *Sow.*	rare.	•	•	•
35. —— entale, *Linn*.....	rare.	.....	.....	•
36. Patella virginea?, young, *Müll.* ... *Ancylus compressus*, Nyst.	rare.	.....	•?	•?
37. Calyptræa sinensis, *Linn*.....	rare.	•	•	•
38. Trochus papillosus, *DaCosta*	.....	.....	•	•
39. Solarium turbinoides, *Nyst*	rare.	•		
40. Scalaria lamellosa, *Brocc*..... *S. fimbriosa*, Wood.	.....	•		
41. Turritella incrassata, *Sow.*	.....	•	•	
42. Eulima subulata, *Montag.*	rare.	•	.....	•
43. Tornatella elongata, *Sow.*	very rare.	•		
44. —— striata, *Sow.*.....	.....	•	•	•
45. Pyramidella læviuscula, *S. Wood*... *P. terebellata*, Nyst.	rare.	•		
46. Natica Sowerbyii, *Nyst*.....	common.	•	•?	
47. —— crassa, *Nyst*	rare.	•		
48. Bulla cylindracea, *Penn.*	common.	•	•	•
49. —— constricta, *Sow.*	common.			
50. —— utricula, *Brocchi*	rare.	.....	.....	•
51. —— acuminata, *Brug.*	rare.	•	.....	•
52. Cancellaria varicosa, *Brocchi*	very rare.	•	•	
53. —— minuta, *Nyst* (? young of *C. planispira*)	rare.			
54. —— Michelinii, *Bellardi*	very rare. one individual.			
55. —— evulsa, *Brander*	very rare. one individual.			
56. Pleurotoma turricula, *Brocc.*	.....	.....	•	
57. —— dubia, *Crist*.....	very rare.			
58. —— cheilotoma?, *Bast.*	very rare.			
59. —— crenulata, *Bast.* ..... *P. Staffelsii*, Nyst.	rare.			
60. —— intorta, *Brocchi*	very rare.	.....	•	
61. Typhis cuniculosus, *Duchastel*	rare.			
62. Cassidaria bicatenata, *Sow.*	very rare.	•	•	
63. Buccinum prismaticum, *Brocc*.....	rare.	•	.....	•
64. Ringicula buccinea, *Brocc.*	common.	•	•	
65. Cypræa europæa, *Gmel.*	very rare.	•	•	•
		42	28	30

Several species of *Foraminifera* (*Nodosaria*, &c.) and several *Bryozoa* are also in M. de Wael's collection from this deposit.

Of the above 65 species of fossil mollusca, all but 16 are found in the Suffolk Crag. This number of exceptions, however, is greater than in the former lists. Most of them are marked as very rare by M. de Wael, and several of these are Rupelmonde Clay species, which may have been washed out of that older formation, such as *Cancellaria evulsa*, *Typhis cuniculosus*, and *Venus incrassata*. In regard to *Cardium turgidum*, a Barton shell, I had no means of comparing it with British specimens.

The proportion of coralline crag shells is 42 out of the 65 species, while there are only 28 common to the red crag. This preponderance of coralline crag species is in favour of the somewhat greater antiquity of the *crag noir*. The proportion also of recent species, 30 in 65, or about 46 per cent., is less than in the upper and middle crag of Antwerp. This would indicate a period more remote from our times, if we could feel sure that several of the extinct species, which are so extremely rare, have not been derived from older beds.

On comparing Tables III. and IV., it will appear that 30 species are common to the *crag gris* and *crag noir*, which, when we consider the total number of known species as fragmentary representations of the marine fauna to which each respectively belongs, indicates a very close approximation in age for the beds in question.

TABLE VI.

Showing the number of fossil species of Mollusca in the three divisions of the Antwerp Crag, and their relation to the Suffolk Crag and Recent fauna.

	Number of species.	Coralline.	Red.	Recent.
Upper or yellow crag of Calloo*	66	46	59	37
Upper or yellow crag of Steuvenberg†	52	39	37	31
Upper crag of Calloo and Steuvenberg united (Tabs. II. III.)	81	56	68	46
Middle crag‡	94	71	76	46
Lower crag§	65	42	28	30

§ 4. *Sands and Iron-sandstone of Diest* (B. 2. Table I. p. 279). *Système Diestien* of M. Dumont.

The series of which I have next to speak has been named by M. Dumont from the town of Diest, about thirty miles N.E. of Brussels, where the strata are of considerable thickness, but where they have yielded as yet no fossils. They consist for the most part of ferruginous sands and beds of a brown iron-sandstone, with occasionally quartzose sands abundantly mixed with green grains, and sometimes of a dark green or bright green glauconiferous sand.

* See Table II. † See Table III. ‡ See Table IV. § See Table V.

On the whole, in mineral character and aspect, they reminded me much of the ferruginous division of the Lower Green Sand in the South-east of England. Occasionally flint-pebbles are intermixed, and sometimes concretions of hydrate of iron are conspicuous. In several localities thin beds of clay separate the sands. I observed cross or false stratification on a large scale in these beds east of Louvain.

I found the hydrate of iron or limonite exceedingly abundant about two miles west of Louvain, on the road leading to Brussels, in the hill called "Montagne de Fer," where bright green grains are mixed with the quartzose sand.

The only spot where organic remains have been as yet observed is three miles east of Louvain, near Kesseloo, a place which I visited in company with M. Nyst, and where we collected casts of a species of *Turbinolia*?, tolerably abundant. In the same locality casts of the *Terebratula grandis* of Blumenbach (*T. variabilis*, Sow.) have been discovered. From the occurrence of this shell, a species very characteristic of the crag of England, together with casts of other genera, M. Nyst inclined many years since to the opinion that the Diest sands belonged to the crag. I have shown the casts in question, presented to me by M. Nyst, to Mr. Davidson, whose accurate knowledge of the Brachiopoda is well known, and he entertains no doubt of the correctness of the determination of this large Terebratula, not only from the form of the shell, but from the impressions of the peculiar processes which are so prominent in the interior. *Terebratula grandis* occurs in the Coralline and Red Crags of Suffolk, and I have seen it in extraordinary abundance in the crag of St. George de Bohon, near Carentan, in Normandy.

In M. Dumont's Report of 1839 I find the Diest sands given as next below the Campinian or Antwerp crag series, and he cites casts of Antwerp shells, *Pectunculus variabilis*, Sow. (*P. pilosus* or *P. glycimeris*, Linn.), and a supposed fragment of *Solen ensis*, as having been found by M. Van Beneden. All evidence of relative age, derived from position, seems to be wanting, or is confined to the fact that the Diest sands overlie the Bolderberg beds to be mentioned in the next section. Without the aid of the organic remains, we could not have decided whether the Diest sands were allied to the Antwerp crag, or to the Bolderberg deposit, or were quite independent of both. Whether they are more nearly related to the *Crag noir*, or to any other of the Antwerp crags before mentioned, is as yet uncertain.

The Diest sands are very conspicuous in Belgium and French Flanders, as forming the capping of hills throughout a great part of the country where the tertiary strata occur. I first saw them at Cassel, near Dunkirk, capping the chain of hills which extends from Cassel into Belgium. On Mont Noir, in particular, the mass crowning the hill consists partly of gravel with a ferruginous cement, and exhibits hollow tubular concretions of hydrate of iron, which in detached masses, as I saw them lying in a gravel-pit, resembled a pile of cannons, or a heap of large iron cylinders used for gas-pipes,

placed horizontally one upon the other. The following list of the casts of fossils from the Diest sands, however imperfect, may at least serve to show the present scanty state of our knowledge of this deposit.

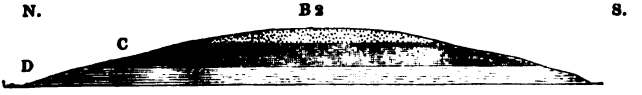
Fossils from the Diest Sands of Kesseloo, near Louvain.

1. Terebratula grandis, *Blum.*
   T. variabilis, Sow.
   T. Sowerbyi, Nyst.
   T. maximus, Charlesworth.
2. Solen ensis ?, *Linn.*
3. Syndosmya prismatica ?, *W. Wood.*
   Ligula donaciformis ?, Nyst.
4. Axinus ?
5. Mactra ?
6. Pectunculus.
7. Cardium.
8. Calyptræa.
9. Natica.
10. Trochus.
11. Buccinum.
12. Fusus.
13. Cerithium.
14. Terebra.
15. Rostellaria.
16. Turbinolia ?

§ 5. *Bolderberg Sands* (C. Table I. p. 279). *Système Bolderien* of M. Dumont.

Between Diest and Hasselt, and about forty miles E.N.E. of Brussels, a small ridge, running nearly N.E. and S.W., and rising to the height of about 50 feet above the plain, and 200 feet, or rather less, above the level of the sea, is called the Bolderberg (see Map). It is situated about five miles N.W. of Hasselt, and its summit is formed of the sands of Diest, already described, below which are some beds of gravel and sand, of small thickness, in which the fossils exhibit a marine fauna, quite distinct from that of the Antwerp crag on the one hand, and that of the Limburg or Kleyn Spawen series on the other.

Fig. 1.—*Section of the Bolderberg.*



B 2. Diest sands and iron-sandstone. D. Limburg sands (*Rupelien* of Dumont).
C. Bolderberg sands and gravel.

In the cutting of a road which traverses the top of the ridge in a direction nearly east and west, and in other openings in the slope of the hill, I saw—

1. The ferruginous sands of Diest, with thin pipes of irony sandstone, in horizontal beds; the whole about 10 or 12 feet thick.
2. Next below, a light green glauconite and layers of brown sand, with mica and quartz grains; 2 feet.
3. A bed of gravel, occasionally cemented into a conglomerate by iron, with numerous fragmentary and some entire shells—this being the principal shell-bed of the Bolderberg formation; 6 inches.
4. Ferruginous and whitish sands; 20 feet
5. Whitish sand and pebbles, with some shells, mostly in fragments, and with numerous large *Ostreæ*; occasionally cemented into a conglomerate; 6 inches?

I may observe that all the shells occur in two beds, the united thickness of which scarcely exceeds a foot, and the broken fragments mixed with pebbles cause them to resemble shells thrown up on a sea-beach.

In the yellow, white, and green sands which underlie these Bolderberg beds, no shells have been found. They are referred by M. Dumont to part of his Rupelian system, but were it not for the accidental preservation of the shells in the gravels Nos. 3 and 5, it would, I conceive, have been impossible to separate the "Bolderian" from the overlying "Diestian," or subjacent "Rupelian" strata. The occurrence of glauconite, which in some countries would furnish a mineral character of considerable use in distinguishing formations, is so universal in Belgium in every tertiary group as to afford no aid whatever.

In a visit of a few hours I obtained specimens of most of the shells hitherto discovered, and the Bolderberg is the only locality where any fossils of this peculiar fauna have been met with in Belgium. The following list of 46 Mollusca and Corals is compiled partly from my specimens, which M. Nyst examined and named, but chiefly from information supplied by M. Bosquet of Maestricht. A large part, however, of the remains are mere casts, and their determination is by no means as satisfactory as could be wished. The notes of interrogation express the doubts entertained by M. Bosquet or by myself on the subject.

List of Fossil Shells and Corals from the Bolderberg near Hasselt.

1. Panopæa.
2. Corbula pisum, *Sow*
3. —— planulata, *Nyst.*
4. Mactra; sp. not determined.
5. Tellina; allied to *T. Benedenii* of the Antwerp Crag.
6. Donax Stoffelsii, *Nyst.*
7. Lucina astartea, *Nyst.*
8. Venus erycina, var. D., *Nyst.*
   V. erycinoides?, Bast.
9. —— chionoides?, *Nyst.*
10. —— rugosa, *Bronn*; so named for me by M. Nyst.
11. —— similis?, *Nyst.*
12. Venus; allied to *V. incrassata*, but more orbicular.
13. Astarte radiata?, *Nyst.*
14. Isocardia harpa, *Goldf.*
15. Nucula Ryckholtiana?, *Nyst.*
16. —— subglobosa?, *Philippi.*
17. Leda interrupta, *Bosq.*
    Nucula interrupta, Poli (Nyst).
18. Pectunculus pilosus, *Nyst.*
    P. glycimeris, Lamk.
19. Arca latisulcata, *Nyst.*
20. Pecten Sowerbyi, *Nyst.*
21. Ostrea; allied to *O. Meadei*, Sow., but different.

22. Phorus, sp. nov. ?
23. Turritella cremulata ?, *Nyst.*
24. —— incisa ?, *Al. Brongniart* (Nyst).
25. Natica; resembling *N. patula*, Lamk.
26. —— olla, *Marcel de Serres.*
27. Sigaretus canaliculatus ?, *Sow.*
28. Cancellaria evulsa, *Brander.*
29. —— planispira, *Nyst.*
30. —— cassidia ?, *Borson.*
31. Angistoma politum, *Bosq.*
    Fusus politus, Bronn.
    Columbella.
32. Pleurotoma ramosa ?, *Bast.*
33. —— turris ?, *Lamk.*
34. —— Stoffelsii, *Nyst.*
35. —— denticula ?, *Bast.*
36. —— acuticosta ?, *Nyst.*
37. —— subcanaliculata ?, *Münst.*
38. —— filosa ?; named for me by M. Nyst.
39. Cerithium crassum, *Dujard.*; in M. Bosquet's collection.
40. Terebra pertusa, var. B., *Basterot.*
41. Eburna; sp. not determined; in M. Bosquet's collection.
42. Conus Brocchii ?, *Bronn.*
43. Ancillaria obsoleta, *Nyst.*
    Buccinum obsoletum, Brocchi.
44. Oliva Dufresnei, *Bast.*; according to M. Nyst, but M. Bosquet doubts this identification, as the Bolderberg species is smaller and shorter, and has numerous striæ on the columella. It is the most abundant shell, though never quite perfect.
45. Flabellum Edwardsianum, *Bosq.*
46. —— avicula, *Nyst* (*Turbinolia avicula*, Michelotti).
47. Lunulites rhomboidalis, *Goldf.*

Although the above list comprises 47 species, so few of them are in a perfect state that we cannot well compare them as a whole with any recent or fossil fauna. Some of the supposed instances of agreement, such as the large *Ostrea* with *O. Meadii* of the 'Mineral Conchology' (an oolite species), are certainly erroneous. Nevertheless, we may at once affirm that we have here an assemblage of organic remains very distinct from the more modern crag of Antwerp or the more ancient Limburg beds.

Some of the species, such as *Isocardia harpa*, are at present peculiar to this locality. The *Oliva Dufresnei* ? is exceedingly plentiful. The genera *Oliva*, *Conus*, *Ancillaria*, and *Cancellaria* imply a warmer climate than that of the Antwerp crag.

In England we have no representative of the Bolderian formation of Dumont; which may possibly be a Miocene deposit, approaching nearer in age to the faluns of Touraine than any other Belgian group. The climate seems to have been not unlike that which prevailed when the faluns of the Loire were deposited.

§ 6. *Limburg Tertiary series* (D. Table I. p. 279). *Système Rupelien* and *Tongrien* of Dumont. Upper Eocene (Lower Miocene of some writers).

The tertiary strata of Belgium, which follow next in the descending series, or which underlie the Bolderberg sands already described, have been long known to palæontologists as the "Kleyn Spawen beds." At the village of Kleyn Spawen, in the ancient province of Limburg, west of Maestricht (see Map), and in the neighbourhood, they exhibit several marked subdivisions in regular order of superposition.

We are indebted to M. Hébert for having in 1849 pointed out the palæontological relation of the Limburg beds to the highest portion of the Parisian series, or, in other words, for having proved them to be the equivalents of strata which Cuvier and Brongniart originally styled "the second marine formation," comprising the *Grès de Fontainebleau* and the green marls with *Ostrea cyathula* which overlie the gypsum*.

After studying the Limburg beds with the advantage of the assistance of M. Bosquet, of Maestricht, I came to the conclusion that they may be most conveniently divided into three groups, of which the uppermost and the lowest are marine, and the middle fluvio-marine. The uppermost member has not afforded as yet in the Kleyn Spawen district, where it is of small thickness, more than thirty-two species of fossils, chiefly Mollusca and Entomostraca (see Table IX.); but at several places on the Scheldt near Antwerp, fifty miles E.N.E. of Kleyn Spawen, especially at Rupelmonde, Boom, Basele, and Schelle, it has yielded a large number of Mollusca. The names of these localities are familiar to the readers of Nyst's 'Coquilles tertiaires de Belgique,' and as I visited them all in the course of the summer I shall now describe them. (See Map, Pl. XVII. fig. 1.)

1. *Rupelmonde Clay* (*Upper Limburg beds*). *Système Rupelien* of M. Dumont (D. 1. Table I. p. 279).

Rupelmonde.

Ascending the Scheldt from Antwerp (see Map), for a distance of about eight miles, to a point just above its junction with a small stream called the Rupel, we see on the left or north bank a line of cliffs half a mile long and about 100 feet high, adjoining the village of Rupelmonde. These cliffs consist chiefly of clay used for brick-making. At the top of the perpendicular precipice appears a bed of sand, varying from 5 to 20 feet in thickness, and below it, a mass of dark clay from 80 to 90 feet thick, under which I was informed whitish sandy strata have been pierced in boring.

The yellow sand at the top, usually about 16 feet thick, is stratified, and in it I found a few fragments of shells, apparently belonging to *Corbula planulata*, Nyst (*C. gibba*, Oliv.), and *Cyprina tumida*, Nyst, to which M. de Wael, of Antwerp, who has better specimens

* Hébert, Bulletin de la Soc. Géol. de France, 2 ser. vol. vi. p. 459, April 1849.

than mine, refers them. I also obtained fragments of an *Astarte*, apparently a crag species; so that I have little doubt of the correctness of M. de Wael's opinion, that this yellow sand represents the upper crag of Antwerp. The dark clay below resembles in mineral character the London clay, and contains, like it, septaria, or concretions of argillaceous limestone traversed by cracks in the interior and occurring in regular layers. The higher beds when dried are thinly fissile. Although a great number of fossil shells are annually collected by the workmen from this clay, I was scarcely able to find any after a search of several hours. The only species I saw *in situ* were *Nucula Deshayesiana*, a fragment of a *Dentalium*, and a Shark's tooth. But I obtained more than twenty species from the labourers.

Schelle and Boom.

The locality of Schelle is seen from Rupelmonde, being on the opposite bank of the Scheldt (see Map, Pl. XVII.). Here I found a mass of clay, from 50 to 60 feet thick, covered by yellow and whitish sand about 6 feet thick.

At Boom, which is on the same side of the river, the Rupelmonde clay is seen about 30 feet thick, covered, as in the other localities, with the yellow sand of the crag, and said to repose on whitish sand full of water, called by the workmen "drift." The great mass of clay at Boom is divided into two beds, at the point of junction of which is a layer of huge septaria. The lower bed, which contains balls of pyrites, is a stiffer clay, and is about 15 feet thick. The upper is more sandy. The only fossils which I myself found were *Pleurotoma Selysii*, *Nucula Deshayesiana*, and an *Anomia*? The shells are said to be dispersed through the clay. The only small species obtainable from the workmen in any locality is *Corbula pisum*, of which I saw no separate individuals, and which would I believe have been neglected but for the accident of their being frequently met with, aggregated together in flattened lenticular masses of pyrites. I suspect, therefore, that the Rupelmonde fauna would be much richer, if naturalists had not hitherto been almost entirely dependent, like myself, for their fossil mollusca on the workmen, who overlook all but the larger and more conspicuous species.

A description of forty-three species of shells from this formation, illustrated by figures of many of the most remarkable, was published, in January 1837, by M. de Koninck*.

M. Nyst has had the kindness to furnish me with a corrected list of those known to him in 1851. I procured specimens of all the more abundant of these, twenty-eight in number, on the spot, and have compared them, with the aid of Messrs. Morris and Edwards, with the very extensive collection of shells from the London Clay in the possession of the last-mentioned of these gentlemen. As the clay of Rupelmonde and Boom has been often regarded as contemporaneous with the London Clay, it was necessary to consult larger

* Mémoires de l'Acad. Roy. des Sciences, &c. de Bruxelles, tom. xi., Descript. des coq. foss. de l'argile de Basele, Boom, Schelle, &c.

collections of the English species than had hitherto been at the disposal of Belgian naturalists, which the kindness of Messrs. Morris and Edwards enabled me to accomplish.

Table VII.

List of Fossils from the Clay of Rupelmonde, Boom, and Sebelle.

Names of species.	Observations.
1. Corbula pisum, *Sow.*	Occurs in England in the Upper Marine, Isle of Wight, in the clay of Barton, and in the Bracklesham beds.
2. Lutraria oblata?, *Sow.*	M. Nyst considers this as a doubtful identification from imperfect specimens, and proposes the name of *L. dubia*.
3. Erycina striatula, *Nyst.*	A shell imperfectly known.
4. Axinus Nystii, *Philippi.* *A. angulatus*, De Kon. *Lucina Goodhallii*?, Sow.	Mr. Morris observes that this shell is closely allied to *Lucina Goodhallii*, Sow. (Geol. Trans. 2 ser. v. tab. 8. fig. 7), a London Clay shell. It is probably, he says, only a local variety. It is distinguished by the deeper lunule, the more produced posterior folds, and divided surface.
5. Astarte Kickxii, *Nyst.*	
6. Venus incrassata, *Sow.*	M. Nyst does not feel sure of this identification, and I could not obtain specimens to compare with the British fossil.
7. Cardita Kickxii, *Nyst.* *C. globosa*, Sow.?	Perhaps a variety of *C. globosa*. It is intermediate, observes Mr. Morris, between two varieties of that shell from Barton in the collection of Mr. Edwards. The Belgian shell is more depressed, and the ribs are somewhat differently ornamented.
8. Leda Deshayesiana.	Larger and thicker than *Nucula emarginatoides* of the London clay, but in the young state much resembling the English shell.
9. Nucula archiacana, *Nyst.*	Very rare; only found as yet in Belgium.
10. — Chastelii, *Nyst.*	Also found at Hermsdorf, near Berlin.
11. Arca decussata, *Nyst.* *A. multistriata*, De Koninck.	A distinct species from *A. duplicata*, Sowerby, with which M. Nyst originally identified it.
12. Pecten Hoëninghausii, *Defr.*	
13. P. Ryckholtii, *Nyst.*	A small, newly discovered species, allied, as I learn from M. Nyst, to *Pecten obsoletus* and *P. sublevigatus*, but "with flatter valves and longitudinal striæ more distinct."
14. Ostrea paradoxa, *Nyst.*	
15. Dentalium Kickxii, *Nyst.*	
16. Phorus Lyellianus, *Bosq.* *Trochus agglutinans*, Nyst.	M. Nyst is now of opinion that this shell differs from *Trochus agglutinans*, Lamk. It has, he observes, a more conical spire.

TABLE VII. (continued).

Names of species.	Observations.
17. Scalaria, new species.	I met with this shell at Rupelmonde, and it will be figured and described in M. Nyst's Supplement. It comes very near to a London Clay species from Potter's Bar, near London, in Mr. Edwards's collection. It differs from *Scalaria costulata*, Nyst, pl. 38, fig. 6, in having nearly twice as many ribs (eighteen to twenty) in each whorl, in being larger, and having the whorls more symmetrically curved.
18. Actæon (Tornatella) simulatus, *Sow.*	Agrees with some varieties from Barton. It is smoother, and has the furrows less broad, than most of the individuals from the English strata.
19. Natica glaucinoides, *Sow.*	Identical with a Highgate or London Clay fossil; compared by Mr. Morris and Edwards.
20. Cancellaria evulsa, *Brander.*	The difference of this shell from that of Barton is too slight to constitute more than a variety. It agrees, says Mr. Morris, more closely with a Bracklesham form.
21. Fusus elongatus, *Nyst.*	Comes very near to a London Clay shell, but different.
22. —multisulcatus, *Nyst.* *F. lineatus*, Sow.?	Very close to *F. lineatus*, a Highgate shell, but the canal is straighter.—J. Morris.
23. — erraticus, *De Kon.*	
24. — Deshayesii, *De Kon.*	
25. — Koninckii, *Nyst.*	Allied to a Highgate shell, but different.
26. — Waëlii, *Nyst.* *F. regularis*, De Kon.	M. Nyst remarks that this species is different from *F. regularis*, Sow., with which it was formerly supposed to agree.
27. — Staquiezii, *Nyst.* *F. scalaroides*, De Koninck.	This small species, says M. Nyst, might be confounded with *F. aciculatus*, Lamk., but is different.
28. Pleurotoma Morrenii, *De Kon.*	Allied to an undescribed species from Highgate.
29. — crenata, *Nyst.* *P. subdenticulata*, Goldf.	Near to, if not a variety of, an unnamed Barton species.
30. — Selysii, *De Kon.*	Identified by Messrs. Morris and Edwards with a shell from Highgate.
31. — Koninckii, *Nyst.*	Very near to a London Clay shell from Potter's Bar, in Mr. Edwards's cabinet.
32. — Waterkeynii, *Nyst.*	Nearly allied to a Highgate shell.
33. — flexuosa?, *Goldf.* *P. acuminata*, Nyst.	M. Beyrich refers this species to *P. flexuosa*, Goldf. It is not *P. acuminata*, Sow.
34. — Bosquetii, *Nyst.*	This species has been supposed identical with *P. rostrata*, Brander, sp., but M. Nyst is now aware that it differs from it.
35. Murex Pauwelsii, *De Koninck.*	
36. — Deshayesii, *Nyst.*	Near to *M. cristatus*, Sow., a London Clay shell.

TABLE VII. (continued).

Names of species.	Observations.
37. Typhis cuniculosus, *Nyst.* *T. muticus*, Sow.?	Mr. Morris thinks this shell is probably a var. of *T. muticus*, Sow.
38. Triton argutum, *Brander.* *T. flandricum*, De Kon.	The Barton shell is a slight variety of this shell, but a variety from Highgate agrees with it.
39. Rostellaria (Chænopus) Sowerbyi, *Mant.* *Chænopus Margerini*, De Kon.	Agrees with the London Clay species, but larger in average size.
40. Cassidaria (Morio) depressa, *V. Buch.*	
41. — calanthica, *V. Buch.*	A rare species which I was unable to obtain.
42. Voluta semiplicata, *Nyst.*	
43. Nautilus ziczac, *Sow.* *Aturia ziczac*, Bronn.	De Koninck's figure agrees well with the London Clay shell. Only one individual ever found.

Several species of Entomostraca have also been met with in the Rupelmonde clay, and described by M. Bosquet*.

I obtained at Rupelmonde, Boom, and Schelle many Sharks' teeth, some belonging apparently to *Carcharodon heterodon*, Ag. of very large size. The following list comprises twelve species which I have in my collection.

Fossil Fish from Rupelmonde, Boom, and Schelle.

1. Carcharodon heterodon?, *Ag.*	One of the late Mr. Dixon's specimens from Bracklesham, now in the British Museum, agrees more closely than fig. 11–16, pl. 28, of Agassiz's 'Poiss. Foss.'
2. —— angustidens, *Ag.*	
3. Oxyrhina xiphodon, *Ag.*	
4. —— trigonodon, *Ag.*	
5. —— Desorii?, *Ag.*	
6. Otodus obliquus, *Ag.*	
7. Lamna elegans, *Ag.*	
8. —— cuspidata?, *Ag.*	
9. —— compressa?, *Ag.*	
10. —— Hopei, *Ag.*	
11. Galeocerdo minor, *Ag.*	
12. Notidanus primigenius, *Ag.*	

Of the 43 species of Mollusca above enumerated, no less than fifteen are supposed to be species found in English Eocene strata, viz. Nos. 1, 2?, 4, 6, 7?, 18, 19, 20, 22?, 29?, 30, 37, 38, 39, 43. It will be seen that four of these are given doubtfully, but, on the other hand, it is remarkable that several others, which are stated to be

* Mém. Couronn. de l'Acad. Roy. de Belgique, tom. xxiv.

nearly allied to undescribed London Clay species, come so near to them, that by some conchologists they might be thought identical. The affinity on the whole is more with the Barton Clay than with older members of the Eocene series. The general aspect of this fauna is so decidedly Eocene, that I am not surprised that M. Archiac, having no means near Antwerp of determining the relative position of the Rupelmonde clay, and knowing that MM. de Koninck and Nyst had identified one-fourth of the shells with English Eocene species, persisted even in 1848 in believing that it was part of the London Clay proper, which it resembles in mineral character, in the colour of its clay, its contained septaria, and its nodules of pyrites*.

The remains of fossil fish from Rupelmonde, as will be seen by the list, consist partly of London Clay and Calcaire grossier species, such as *Otodus obliquus*, *Lamna elegans*, and *L. compressa*, and partly of species cited by Agassiz as from the "molasse" of Switzerland.

Of the 28 species of shells which I myself obtained at Rupelmonde and the vicinity, the most abundant by far was *Nucula Deshayesiana*, and after it *Fusus multisulcatus*. The occurrence of seven species of *Pleurotoma*, some of them very common, is also a striking character, from which, and from a consideration of the whole of the data comprised in the foregoing list, my friend Professor E. Forbes infers that the clay of Rupelmonde was deposited in a sea at about the junction of his perilittoral and median zones of depth, or between 15 and 25 fathoms, probably nearer to 15 than to 25†.

It will be necessary to defer the consideration of the true age of the Rupelmonde Clay, until I have described the tertiary strata of the province of Limburg.

2. *Tertiary Strata in the neighbourhood of Kleyn Spawen, near Maestricht. Limburg Tertiaries.*

I have already alluded to the services rendered by MM. de Koninck and Nyst to the palæontology of Belgium by their description of the Rupelmonde fossils. The greater part of the Kleyn Spawen Mollusca have also been figured and described by M. Nyst, while M. Bosquet has recently given us an able account of the Entomostracous Crustaceans of the same district. The last-mentioned naturalist has

* Archiac, Hist. des Progr. tom. ii. p. 498.

† As Professor Forbes has recently modified his nomenclature of the zones of depth, in order to render his terms more applicable to the seas of all climates and all parts of the globe, I give the subjoined explanation of his new names as used in this memoir:—

Marine Zones of Depth, according to Prof. E. Forbes, 1852.

Names.	*Depths.*
Littoral zone	Between tide-marks.
Perilittoral zone { Upper or Laminarian division / Lower }	0 to 15 fathoms.
Median (or Coralline) zone { Upper Median / Lower Median }	15 to 30 „ / 30 to 50 „
Infra-median zone	15 to 100 „
Abyssal zone	100 to „

x 2

also laboured successfully in distinguishing the fossils of the several strata, observing which are peculiar to each, and which of them common to different members of the series, so that after I had visited the principal localities in his company, I was able to make myself master of a great body of information which it would have required years of unassisted labour to acquire. In tracing the subdivisions of the strata from one locality to another, and in identifying them in different places by aid of mineral character, we had the advantage of having been preceded by M. Dumont, whose patient and conscientious labours in constructing the map of Belgium cannot be too highly estimated. The task of unravelling the geological relations and geographical limits of the several groups in such a region is attended with no ordinary difficulties, in consequence of the frequent dearth of organic remains, and on account of a deep and almost continuous covering of loess. The resemblance to the older strata, moreover, of some deposits of loess, formed at the expense of denuded tertiary beds and containing the same fossils, adds greatly to the confusion.

After visiting Bergh, Vieux Jonc, Hoesselt, and Lethen near Kleyn Spawen (see Map, Pl. XVII. fig. 4), and the villages of Neerepen and Grimittingen, places familiar to the student of Nyst's work on the fossil shells of Belgium, and after considering the data liberally supplied to me by M. Bosquet, I thought it most useful, at least as a provisional classification, to divide the Limburg tertiaries into Upper, Middle, and Lower (D 1, D 2, and D 3, Table I. p. 279), the first and last being marine, and the middle a fluvio-marine deposit.

Table VIII.

Limburg Beds near Kleyn Spawen.

		Thickness.
Upper (marine) ...	Nucula-loam ("couche argilo-sableuse à Nucules," Bosquet)	3 feet.
Middle (fluvio-marine)	*a.* Bergh sands	14 "
	b. Yellowish sands	6 "
	c. Green marls	36 "
Lower (marine)...	Glauconiferous sandy clay, or *Ostrea sentilabrum* bed	20 "

The uppermost bed of the above Table, called "the Nucula loam," at Bergh is a mixture of sand and clay, in which the twenty-one species of Mollusca and eleven species of Entomostraca, enumerated in the second column of asterisks in Table IX. p. 312, occur. The *Nucula Lyelliana*, Bosq., is the most common shell of this bed, though difficult to obtain entire, owing to its fragile condition. All the other shells are rare except the *Corbulomya complanata*, which is the only one of the whole not decidedly marine. Next to *Nucula Lyelliana* the *Cytheridea Mulleri*, Bosq., is the commonest fossil. In regard to the probable depth of the sea, Prof. E. Forbes supposes it to indicate the lower part of his perilittoral zone.

Of the twenty-one species of Mollusca the following twelve species are common to this bed and to the clay of Rupelmonde, Boom, &c.,

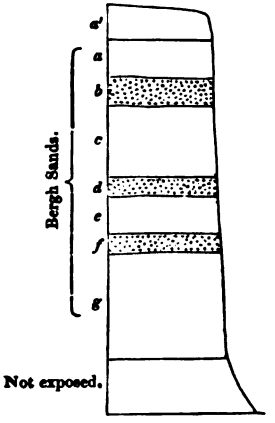
near Antwerp, already described, which (allowing for the small number of species in each) affords decisive palæontological evidence of their contemporaneous origin:—

Axinus Nystii.
Venus incrassata.
Natica glaucinoides.
Fusus elongatus.
Pleurotoma crenata.
—— flexuosa.
Murex Deshayesii.
Typhis cuniculosus.
Triton argutum.
Tritonium flandricum.
Rostellaria (Chænopus) Margerini.
Cassidaria depressa.
Voluta semiplicata.

Of the eleven species of Entomostraca above referred to, several are common to Rupelmonde, Boom, &c.

Next in the descending series we enter on the Middle Limburg beds, or the Bergh sands, *a*, Table VIII. By reference to the accompanying section, fig. 2, it will be seen that the first fossiliferous bed, *b*,

Fig. 2.—*Section of the Bergh Sands* (*a*, Table VIII.) *at Bergh, near Kleyn Spawen.*



	ft.	in.
a'. Nucula-loam	2	0
a. White sand without shells	2	0
b. Pectunculus-bed	1	6
c. White sands without shells	4	0
d. Shelly sand with *Cerithia*	0	6
e. Sand without shells	1	6
f. Shelly sand with *Cerithia*	1	0
g. White sand with few shells (*Cyprina Nystii*).		

of this division is called the Pectunculus-bed, from the extraordinary abundance in it of *Pectunculus fossilis*, Kon. (*P. terebratularis*, Lamk.). The following are the shells which have been met with:—

Fossils of the "Pectunculus-bed" at Bergh, near Kleyn Spawen.

Corbula Henckeliusiana.
Astarte Henckeliusiana (2).
—— trigonella.
Lucina tenuistria.
Cyprina islandica?
—— Nystii.
Venus lævigata (1).
—— incrassata.
Cardita Omaliana.
Pectunculus fossilis (6).
—— pulvinatus (2).
Limopsis Goldfussii (1).
Pecten Hoëninghausii (2).
—— Deshayesii.
Dentalium acutum (1).
Infundibulum striatellum.
Trochus Kickxii.
Natica hantoniensis.
Voluta Rathieri.

Myliobates.
Lamna contortidens.
—— cuspidata.

The seven species to which numbers are appended are the most common, and the numbers indicate the relative abundance of individuals according to M. Bosquet's observations. From the above data Professor Forbes infers that this Pectunculus-bed was probably formed at the junction of his perilittoral and median zones, or at the depth of from 15 to 20 fathoms. There is an absence here of *Cerithia* and other brackish and freshwater species.

The next fossiliferous bed (*d*, section, fig. 2), separated from the former by 4 feet of white sand without shells, is only 6 inches thick. It consists of a shelly sand with *Cerithia*, below which is another bed of sand without shells, and then a second layer of shelly sand with *Cerithia* (*f*, fig. 2). The shells in the two beds (*d* and *f*) are almost identical, but their proportional numbers differ slightly.

Fossils in Beds d and f, White Shelly Sands with Cerithia, at Bergh.—M. Bosquet.

	"*d*"	"*f*"		"*d*"	"*f*"
Corbula pisum	1	1	Pectunculus pulvinatus	1	1
Corbulomya triangula	2	3	Pecten Hoeninghausii	1	1
—— complanata	1	1	Paludestrina Draparnaudii	2	3
Astarte Henckeliusiana	1	1	Rissoa ? Chastelii	2	3
Cyrena semistriata	2	3	—— plicata	1	1
Lucina striatula	1		Rissoina Nystii	2	3
—— Thierensii	2	2	Cerithium subcostellatum	3	4
Venus incrassatoides	1	1	—— elegans	1	2
—— Kickxii	1	2	Pleurotoma belgica	1	1
Cardita Omaliana	1	1	Buccinum Gossardii	1	1
Cardium tenuisulcatum	1	1	Voluta Rathieri	1	1
Limopsis Goldfussii	2	3	Cytheridea Mulleri	1	1
Pectunculus fossilis	1	1			

The numbers appended denote the relative abundance of the several species, *Cerithium subcostellatum* (*C. plicatum*, Lamk.) being the most common. It will be observed that the freshwater and brackish water species are represented by a larger number of individuals in *f*, or in the lower bed. Prof. E. Forbes infers that these strata were formed in the upper part of his perilittoral zone, or in depths varying from low tide-mark to 6 or 7 fathoms.

In the Bergh sands the following six species are often much rolled: *Cyrena semistriata*, Desh., *Venus incrassatoides*, Nyst, *Pyramidella cancellata*, Nyst, *Rissoa plicata*, Desh., *Cerithium elegans*, Desh., and *Cerithium subcostellatum*, Schloth. But M. Bosquet remarks that some individuals even of these species are so perfect as to appear to have lived on the spot, and that there is no ground for inferring that such species were washed out of older beds, or that they did not inhabit rivers or estuaries communicating with the sea in which the white sands of Bergh were formed.

Beneath "*f*" of section, fig. 2, are white sands several feet thick, without fossils, except that a few specimens of *Cyprina Nystii* have been met with; and there is then a break in the section at Bergh at the place of the yellow sands (*b*, Table VIII. p. 304) which occur at Kleyn Spawen and Vieux Jonc, interposed between the white sands of Bergh (*a*, Table VIII.) and the green marls (*c*) of the same table.

Fossils of b, Table VIII., *or Yellowish Sands of Kleyn Spawen, in the collection of M. Bosquet.*

Panopæa Hebertiana, *Bosq.*
Corbulomya complanata, *Nyst.*
—— triangula, *Nyst.*
Corbula pisum, *Sow.*
Erycina neglecta, *Nyst.*
Psammobia rudis, *Lamk.*
Tellina Hebertiana, *Bosq.*
Lucina Thierensii, *Héb.*
—— tenuistria, *Héb.*
—— striatula, *Nyst.*
Cyrena semistriata, *Desh.*
Venus Kickxii, *Nyst.*
—— incrassatoides, *Nyst.*
Limopsis Goldfussii, *Bosq.*
Pectunculus terebratularis, *Lamk.*
Mytilus fragilis, *Nyst.*
—— Faujasii, *Al. Brong.*
Trochus striatellus, *Bosq.*
Paludestrina Draparnaudii, *Bosq.* (1)
Paludestrina pupa, *Bosq.*
Rissoina Nystii, *Bosq.* (1)
Rissoa ? Chastelii, *Bosq.* (1)
—— plicata, *Desh.* (1)
Turbonilla lævissima, *Bosq.*
Pyramidella cancellata, *Nyst.*
Nerita concava, *Sow.*
Natica glaucinoides ?, *Sow.*
Pleurotoma costellaria, *Duchast.*
Cerithium elegans, *Desh.* (3)
—— subcostellatum, *Schlt.* (6)
C. plicatum, Lamk.
—— incrassatum, *Merian.*
—— lima, *Desh.*
Buccinum Gossardii, *Nyst.*
—— suturosum, *Nyst.*
Cytheridea Mulleri, *Bosq.* (1)
—— Williamsoniana, *Bosq.*
Cythere Jurinei, *Münster.*

It will be seen that the only abundant shells in *b*, Table VIII., are fresh or brackish water species, and that *Cerithium subcostellatum* is the most frequent. According to Professor Forbes, this bed was formed in a shallow part of the perilittoral zone.

Next in the descending order are the green marls and clays, *c*, Table VIII., the Upper Tongrian of Dumont, which occur below the yellowish sands (*b* of the same Table). Their thickness at Lethen, Vieux Jonc, Hénis, and other localities which I visited is considerable (not less than 36 feet at Lethen), and they appear to indicate many oscillations of the water from a fresh to a brackish state. Sometimes, for example, a thin bed occurs almost exclusively characterized by *Venus incrassatoides* and *Lucina Thierensii*, then a layer with *Cyrena semistriata*, then another with *Cerithia*. I found occasionally at Lethen a well-rounded flint-pebble in the midst of these green clays and marls.

In the following list of seventeen species belonging to this subdivision, the relative abundance of the fourteen commonest species is expressed by numbers supplied by M. Bosquet. Prof. Forbes infers from them and the fossils generally that these clays were deposited in his perilittoral zone, in the neighbourhood of the influx of fresh water.

Fossils of the Green Marls, c, Table VIII. (*part of the Middle or Fluvio-marine Limburg Beds*).

Corbula pisum	2	Rissoa plicata	
—— complanata	1	—— ? Chastelii	1
Corbulomya triangula	2	Rissoina Nystii	2
Cyrena semistriata	4	Pyramidella cancellata	
Lucina Thierensii	2	Natica glaucinoides	1
Tellina Hebertiana	1	Cerithium subcostellatum	5
Venus incrassatoides	5	—— elegans	3
Trochus striatellus		Cytheridea Mulleri	6
Paludestrina Draparnaudii	2		

We now come to the Lower Limburg or Lower Tongrian beds, consisting of clayey greensand 20 feet thick, to which the 108 fossils enumerated in the "Lower" column of Table IX. p. 312, belong, and in which *Ostrea ventilabrum* is everywhere a common and conspicuous fossil. The uppermost beds of this deposit, which I saw at Lethen and at Grimittingen, where they are close to the green marls (*c* of Table VIII. above mentioned), are characterized, observes M. Bosquet, by the abundance of *Turritella crenulata*.

Upper portion of Lower Limburg, Table VIII. p. 304 (*Lower Tongrian*).
Most abundant species of Fossil Shells according to M. Bosquet.

	Relative abundance.		Relative abundance.
Corbula pisum, *Sow.*	1	Ostrea ventilabrum, *Goldf.* ...	6
Lucina gracilis, *Nyst*	1	—— cochlear, *Poli*	3
Pectunculus lunulatus, *Nyst* ...	1	Dentalium acutum, *Héb.*	1
Arca sulcicosta, *Nyst*	2	Turritella crenulata, *Nyst*	3

The lower beds of the same are seen at Hoesselt near Kleyn Spawen and at Grimittingen.

Most abundant species of Fossil Shells in the lower portion of the fossiliferous Lower Limburg beds.

	Relative abundance.		Relative abundance.
Corbula pisum, *Sow.*	1	Janira (Pecten) incurvata, *Besq.*	1
Crassatella intermedia, *Nyst* ...	1	Ostrea ventilabrum, *Goldf.* ...	5
Isocardia transversa, *Nyst* ...	2	—— carinosa, *Desh.*	3
Cardita latisulca, *Nyst*	1	—— cochlear, *Poli*	2
Arca sulcicosta, *Nyst*	1	Dentalium acutum, *Hebert* ...	1
Mytilus Nystii, *Kickx*	3	Voluta suturalis, *Nyst*	1
Pecten reconditus, *Brander* ...	2		

Professor Forbes refers these lower beds, which are purely marine, to the upper part of his median (or coralline) zone. He supposes that the inferior beds indicate a muddy bottom, which was at a somewhat greater depth in the same zone than that in which the superior ones were formed.

It will be seen by consulting Table IX. p. 312, that the Lower Limburg beds out of 106 species of mollusca have no less than 68 peculiar to themselves, only 38 species passing upwards into the Middle and Upper Limburg divisions. All these 106 species are purely marine, except *Corbulomya complanata*, found at Lethen in the upper part of the bed.

The distinctness of so many of these Lower Limburg fossils from the species occurring in the beds immediately above, arises no doubt in a great degree from a difference in *stations*, or in the fauna of the the median as compared to that of the perilittoral zone. But the changes in time may also have been great during those ages when the sea and a river were contending for the occupation of the area in which the middle Limburg strata were thrown down.

3. *Micaceous Sands of Hénis, Geulem, Klimmen, &c.*

On the right bank of the Meuse opposite Maestricht, the most eastern locality where I saw the Limburg tertiaries, they consist of whitish and yellowish micaceous sands without fossils. I observed them at Geulem, about five miles N.N.E. of Maestricht. The uppermost part of the section in that place exhibits loess and gravel, 25 feet thick, below which is 20 feet of white and greyish sand, followed by yellowish sand with mica, 10 feet thick, and lastly Maestricht chalk. I learn from M. Bosquet, that at Klimmen, on the same side of the Meuse, near Fauquemont, are white sands in a similar position, about 30 feet thick, in which he found *Venus incrassata* and some other fossils ill-preserved, but none which showed distinctly whether these sands are referable to the Lower or Middle Limburg series.

I observed similar beds at Hénis, immediately below the green marls of the middle division (*c*, Table VIII. p. 304). The sands also at Predikheerenberg, near Louvain, mentioned by M. Dumont as underlying the Rupelmonde clay of that locality, may belong to the same division, but, in the absence of strata containing *Ostrea ventilabrum* and other characteristic lower Limburg shells, it seemed to me impossible to settle the true age of such sands.

4. *Relation of the Rupelmonde and Boom Clay to the Upper Limburg Beds.*

An important notice was read to the Royal Academy of Brussels by M. Dumont, in 1851, "On the geological position of the Rupelian clay*," in which he announced the discovery at Predikheerenberg and Lubbeck, near Louvain, of clay with septaria, precisely resembling in mineral character that of Rupelmonde and Boom, and containing several characteristic species of fossil shells, as *Leda Deshayesiana*, *Nucula Chastelii*, and *Astarte Kickxii*. This schistose clay reposes on sand, in which casts and impressions of fossils referred to *Pecten Hoëninghausii*, *Pectunculus fossilis*, Kon. (*P. terebratularis*, Lamk.), and *Cyprina Nystii*, all of them middle Limburg shells, have been met with.

I visited the localities myself, in company with M. de Koninck, and have no doubt that the dark schistose clay at Lubbeck and some neighbouring places corresponds to that of Rupelmonde. It is covered by the Diest sands, and rests on other sands which belong to some part of the Limburg beds below the "Nucula-loam" (Table VIII. p. 304); the state of decomposition, however, of the organic remains found in them makes it somewhat rash at present to assign to the sandy beds an exact position in the series.

The middle Eocene strata, or Brussels beds, are seen near the base of the hill of Predikheerenberg, not far from the village of Parc, and in the suburbs of the town of Louvain, near the Tirlemont gate.

* Acad. Roy. de Belgique, tom. xviii. no. 8. des Bulletins, lue le 2 Août 1851.

A. Rupelmonde.	Thickness. Feet.
1. Yellow crag	15
2. Rupelmonde clay, with *Leda Deshayesiana*, &c.	90
3. White sands (Middle Limburg sands?) pierced by boring... } Unknown.	

B. Louvain.	Thickness. Feet.
1. Diest sands	4 to 20
2. Clay with *Leda Deshayesiana*, &c. ...	2 to 10
3. Sands with Middle Limburg fossils ...	40
4. Brussels beds, or Middle Eocene. } Unknown.	

C. Bergh and Kleyn Spawen, Limburg.	Thickness. Feet.
1. Loess	15
2. Nucula-loam with many Rupelmonde fossils	3
3. Sands and green marl (Middle Limburg)	36
4. Lower fossiliferous Limburg beds with *Ostrea ventilabrum*	20

On comparing the accompanying three sections, A., B., and C., the nature of the evidence in favour of considering the Rupelmonde clay to be the equivalent of the Upper Limburg or "Nucula-loam" of Bergh, near Kleyn Spawen, may be readily appreciated. It will be necessary for the reader to bear in mind that the Louvain section, B., is geographically intermediate between A. and C.; Louvain being only twenty miles south-east of Rupelmonde, and forty miles west of Kleyn Spawen. The identity of the clays No. 2 in A. and B. is shown both by the similarity of their mineral character and contained septaria, and by the presence of *Leda Deshayesiana* in abundance. The intimate relation of the bed No. 2 in A. and C. is shown by the large number of fossil species common to both, as before stated, p. 304.

5. *On the Loess near Kleyn Spawen, and on the Denudation of the Limburg Tertiary strata.*

Before presenting the reader with a general Table of the Limburg fossils, and with such observations as they suggest, I must say a few words on the manner in which the Loess and associated alluviums occur near Kleyn Spawen, sometimes putting on the appearance of regular tertiary strata.

Fig. 3.—*Section at Lethen near Bilsen, Limburg.*

A. Loess of the ordinary character.
D 2. Middle Limburg series. Upper part, green marl; the lower, X, grey sand, and green clay and sand, unfossiliferous.
D 3. Lower Limburg beds. Sand with *Ostrea ventilabrum*.
a. Greenish sandy clay. } Modern alluvium.
a'. Yellowish sandy clay. }

Near Lethen, for example, the annexed section is seen on the slope of the ground towards the valley of the Damer. When I first examined, with M. Bosquet, the beds, *a*, *a'*, consisting of greenish clay and sand, and containing *Corbula pisum*, *Cerithium subcostellatum*, *Cyrena semistriata*, and many other Middle Limburg fossils, I sup-

posed them to be a part of the regular series, or Lower Limburg beds, but M. Bosquet made excavations after we parted, which proved the order of superposition to be as in the above section. He also found, on washing the alluvial clay or loam, *a*, *a'*, that it included many Foraminifera of the Maestricht chalk, such as *Rosalina depressa*, D'Orb., *Siderolina calcitrapoides*, Lamk., &c.; also Bryozoa, from the same, of the genera *Vincularia*, *Idmonea*, *Pustulopora*, and others, besides several Entomostraca, in all twelve cretaceous fossils. These must have been brought down from the region between Tongres, Liege, and Maestricht, or from the upper sources of the Damer, where the Maestricht chalk exists, and the fossils were mixed up with those of the denuded tertiary strata. The waters of the Damer must have risen 40 or 50 feet above their present level to have deposited the more elevated part of these modern alluviums.

At Hoesselt a remarkable bed of pebbles, 1½ foot thick, occurs in an analogous position, composed of well-rolled flint-pebbles, with an abundance of large oysters (*Ostrea ventilabrum*) and other fossils. This gravel rests on the Lower Limburg sands; it is nearly horizontal, and does not follow the slope of the ancient valley, scooped out of the tertiary strata, which it has partially filled up. The shells which M. Bosquet has found in it belong to no less than 49 species, by far the greater part of them Middle or Upper Limburg species, and usually much rolled; whereas the Lower Limburg shells, especially the smaller species, have suffered very little. Some of the flint-pebbles in this gravel are 4 or 5 inches in diameter. At first sight the mixture of freshwater and brackish water shells with rolled marine species, reminded me of parts of the Woolwich pebble-beds belonging to the lower Eocene, near London.

At Grimittingen also, and at Neerepen, I met with pebble-beds overlying the Lower Limburg tertiaries, which M. Dumont refers to the age of the Loess. They contain *Cyrena*, *Pectunculus*, and various Middle Limburg shells, and some of them are with difficulty distinguishable from part of the regular series, which also, even where it is undisturbed, as at Lethen, includes rolled flint-pebbles, and, as in the case of the sands of Bergh, before alluded to (p. 306), rolled fossils.

At Neerepen, the task of drawing the line between the incumbent loess and the fluvio-marine tertiary beds is still more difficult. The two deposits are laid open to view in a deep lane. The loess in its upper part consists of a fine yellowish grey loam, as in the valley of the Rhine; and this was the only spot in Belgium where I found it to contain *Succinea oblonga*, which so generally characterizes it in the Rhine valley, and *Helix plebeia*? or *hispida*?. Still lower the same species of land-shells are again seen, in a bed in which entire *Cerithia* and other tertiary shells abound, so intimately blended, that no geologist visiting the district for the first time would suspect them to be of different ages. M. Bosquet found here an Elephant's tusk, 2 feet long, extending from the loess into the stratum full of *Cerithia* and tertiary shells. At a lower level is a pebble-bed, from 3 to 4 feet thick, containing *Corbula pisum*, *Pectunculus pilosus*, *Corbulomya triangula*, *Cyrena semistriata*, and several species of *Cerithia*. This

stratum had all the appearance of an undisturbed tertiary bed, but is probably, like that of Hoesselt, of later origin.

6. *Synoptical Tables of the Limburg fossils.*

The following synoptical Table of the organic remains of the Limburg tertiary strata has been communicated to me by M. Bosquet, and I have inserted a column for the Rupelmonde species, given more in detail in Table VII. A large portion of the Mollusca have been compared by me in London with British fossils, with the assistance of MM. Morris, Edwards, E. Forbes, and other eminent palæontologists.

Table IX.

Fossils of the Rupelmonde and Kleyn Spawen Beds, or of the Upper, Middle, and Lower Limburg Beds:—M. Bosquet.

The first column of asterisks refers to the fossils of the clay of Rupelmonde, Boom, &c. near Antwerp. The second, to the fossils of the "Nucula-loam," Table VIII. The third, to the fossils of *a*, *b*, *c*, Table VIII., or the white and yellow sands and green marls of Bergh, Kleyn Spawen, Lethen, &c., constituting the Middle or Fluvio-marine Limburg series. And the fourth column, to the fossils of the Lower Limburg, or "Ostrea ventilabrum beds."

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower.
Corallia.				
1. Turbinolia sulcata, *Lam.*	.....	.....	.....	*
2. Dendrophyllia amica, *Milne-Edw. & Haime*	.....	.....	.....	*
				2
Mollusca.				
1. Clavagella tibialis ?, *Lamk.*	.....	.....	.....	*
2. Pholas cylindrica ?, *Sow.*	.....	.....	*	
3. Solen ensis, var. *b*, minor, *Lamk.*	.....	.....	*	
4. Leguminaria papyracea, *d'Orbigny* (*Desh.*)	.....	.....	.....	*
5. Solecurtus compressus, *Nyst* *Sanguinolaria compressa*, Sow.	.....	.....	*	*
6. —— appendiculatus, *Nyst* (*Lamk.*)	.....	.....	*	
7. Panopæa Hebertiana, *Bosq.* *P. intermedia*, Nyst, non Desh.	.....	.....	*	
8. Mya angustata ?, *Sow.*	.....	.....	*	
9. Lutraria oblata ?, *Sow.* *Thracia oblata*, Morris.	*			
10. Corbulomya complanata, *Nyst* (*Sow.*)	.....	*	*	*
11. —— triangula, *Nyst* (*Duchast.*)	.....	.....	*	
12. Corbula Henckeliusiana, *Nyst*	.....	.....	*	*
13. —— pisum, *Sowerby*	*	.....	*	*

TABLE IX. (continued).

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower.
14. Corbula striata, *Lamarck*	.....	.....	*	*
15. —— fragilis, *Nyst*..	.....	.....	.....	*
16. Crassatella intermedia, *Nyst*	.....	.....	.....	*
17. Astarte Henckeliusiana, *Nyst*	.....	.....	*	
18. —— Omalii, *Lajonk.*, var. D., *Bosquet* ...	.....	.....	*	*
19. —— trigonella, *Nyst*	.....	.....	*	
20. —— Bosquetii, *Nyst*	.....	.....	*	*
21. —— Kickxii, *Nyst*, var. B., *Bosquet*	*	.....	.....	*
22. —— plicatella, *Bosq.*	.....	.....	.....	*
23. Erycina neglecta, *Nyst*	.....	.....	*	
24. —— striatula, *Nyst*	*			
25. Ligula fragilis, *Bosq.*	.....	.....	*	*
26. —— brevis, *Bosq.*	.....	.....	.....	*
27. Psammobia rudis, *Lamk.*	.....	.....	*	
28. Tellina Hebertiana, *Bosq.*	.....	.....	*	
29. Lucina gracilis, *Nyst*	.....	.....	.....	*
30. —— Thierensii, *Hébert* *L. albella*, Nyst.	.....	.....	*	
31. —— tenuistria, *Hebert* *L. uncinata*, Nyst.	.....	*	*	
32. —— lepida, *Bosq.* *L. divaricata*, Nyst.	.....	.....	*	
33. —— striatula, *Nyst*	.....	.....	*	
34. Diplodonta apicalis, *Philip.* *D. parvula*, Nyst.	.....	.....	.....	*
35. Axinus Nystii, *Philip.* *A. angulatus*, De Kon. *Lucina Goodhallii*?, Sow.	*	*	.....	*
36. Cyrena semistriata, *Desh.*	.....	.....	*	
37. Cyprina Nystii, *Hébert* *C. scutellaria*, Nyst.	.....	.....	*	
38. —— islandica, var. *a*, *Nyst*?	.....	*	*	
39. Venus sublævigata, *Nyst*	.....	.....	.....	*
40. —— sulcataria, *Nyst* *V. Bosquetii*, Hébert.	.....	*	.....	*
41. —— lævigata, *Nyst* (*Lamk.*)	.....	.....	*	*
42. —— Kickxii, *Nyst*	.....	.....	*	
43. —— incrassata, *Sow.*	*	*	*	*
44. —— incrassatoides, *Nyst*	.....	.....	*	
45. —— Westendorpii, *Nyst*	.....	.....	*	
46. Cardium hippopæum, *Desh.*	.....	.....	.....	*
47. —— porulosum, *Brander*	.....	.....	.....	*
48. —— tenuisulcatum, *Nyst*	.....	.....	*	*
49. —— elegans, *Nyst*	.....	.....	.....	*
50. —— Raulini, *Hébert*	.....	.....	*	
51. —— scobinula, *Mérian* *C. striatulum*, Nyst.	.....	.....	*	

TABLE IX. (continued).

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower
52. Isocardia transversa, *Nyst*	.....	.....	.....	*
53. —— multicostata, *Nyst*	.....	.....	... .	*
54. —— carinata, *Nyst*	.....	.....	.....	*
55. Cypricardia pectinifera, *Morr.* (*Sow.*)	.....	.....	.....	*
56. Cardita latisulca, *Nyst*	.....	.....	.....	*
57. —— Omaliana, *Nyst*	.....	.....	*	
58. —— Kickxii, *Nyst* ..... *C. globosa*, Sow.?	*			
59. Leda Galeottiana, *Bosq.* (*Nyst*)	.....	.....	.....	*
60. —— Westendorpii, *Bosq.* (*Nyst*)	.....	.....	*	
61. —— Deshayesiana	*			
62. Nucula similis, *Sow.*	.....	.....	.....	*
63. —— subtransversa, *Nyst*	.....	.....	*	
64. —— Lyelliana, *Bosq.*	.....	*		
65. —— archiacana, *Nyst*	*			
66. —— Chastelii, *Nyst*	*			
67. Limopsis scalaris, *Bosq.* (*Nyst*)	.....	.....	.....	*
68. —— auritoides, *Bosq.* (*Galeotti*)	.....	.....	.....	*
69. —— Goldfussi, *Bosq.* (*Nyst*)	.....	.....	*	
70. Pectunculus fossilis, *De Koninck* ..... *P. terebratularis*, Lamk.	.....	.....	*	
71. —— pulvinatus, *Nyst*, non *Lamk.*	.....	.....	*	
72. —— lunulatus, *Nyst*	.....	.....	.....	*
73. —— nummarius?, *Lamk.*	.....	.....	.....	*
74. Arca sulcicosta, *Nyst*	.....	.....	.....	*
75. —— decussata, *Nyst* ..... *A. multistriata*, De Kon.	*			
76. Mytilus Nystii, *Kickx*	.....	.....	.....	*
77. —— corrugatus?, *Brongn.*	.....	.....	*	
78. —— fragilis, *Nyst*	.....	.....	*	
79. —— Faujasii, *Brongn.*	.....	.....	*	
80. Dreissena Basteroti, *Nyst* (*Desh.*)	.....	.....	*	
81. Pinna affinis?, *Sow.*	.....	.....	.....	*
82. Pecten reconditus, *Nyst* (*Brander*)	.....	.....	.....	*
83. —— corneus, *Sow.*	.....	.....	.....	*
84. —— Deshayesii, *Nyst*	.....	.....	*	
85. —— tigerinus, *Müller*, var. F. ..... *P. novemcostata*, Bosq.	.....	.....	*	
86. —— Hoëninghausii, *Def.* ..... *Janira Hoëninghausii*, Bosq.	*	.....	*	*
87. —— Ryckholtii, *Nyst*	*			
88. —— incurvatus, *Nyst* ..... *Janira incurvata*, Bosq. (Nyst).	.....	.....	.....	*
89. Spondylus auriculatus, *Nyst*	.....	.....	.....	*
90. —— Buchii, *Philip.*	.....	.....	.....	*
91. Anomia orbiculata?, *Broccki*	.....	.....	.....	*
92. Ostrea cochlear?, *Poli*	.....	.....	.....	*

TABLE IX. (continued).

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower.
93. Ostrea ventilabrum, *Goldf.*	.....	.....	.....	*
94. —— cariosa, *Desh.*	.....	.....	.....	*
95. —— gigantea, *Brander*	.....	.....	*	
96. —— bellovacina?, *Lamk.*	.....	.....	*	
97. —— paradoxa, *Nyst*	*			
98. Dentalium Kickxii, *Nyst*	*			
99. —— acutum, *Hébert*	.....	.....	*	*
D. grande, Nyst, non Desh.				
100. —— fissura, *Lamk.*	.....	.....	*	*
101. Emarginula Nystiana, *Bosq.*	.....	.....	*	*
102. Capulus cornu-copiæ, *Bronn* (*Defr.*)	.....	.....	*	*
103. Infundibulum striatellum, *Bosq.* (*Nyst*)	.....	*	*	*
104. —— lævigatum, *Bosq.* (*Desh.*)	.....	.....	*	
105. Solarium Dumontii, *Nyst*	.....	.....	.....	*
106. Phorus extensus?, *Pusch*	.....	.....	.....	*
107. —— Lyellianus, *Bosq.*	*	.....	*	
Trochus agglutinans, Nyst.				
108. Trochus Kickxii, *Nyst*	.....	.....	*	
109. —— striatellus, *Bosq.*	.....	.....	*	
110. Scalaria costulata, *Nyst*	.....	.....	*	
111. ——, nov. sp.	*			
112. Ampullaria mutabilis, *Nyst*, non *Brander.*	.....	.....	*	*
Globulus, Sow.				
113. Turritella crenulata, *Nyst*	.....	.....	.....	*
114. —— planispira, *Nyst*	.....	.....	.....	*
115. Paludestrina Draparnaudii, *Bosq.*	.....	.....	*	
Paludina, Nyst.				
116. —— pupa, *Bosq.* (*Nyst*)	.....	.....	*	
117. Rissoina Nystii, *Bosq.* (*Duchast.*)	.....	.....	*	
Melania Nystii, Nyst.				
118. Rissoa? Chastelii, *Bosq.*	.....	.....	*	
Paludina Chastelii, Nyst.				
119. Rissoa plicata, *Desh.*	.....	.....	*	
R. violacea?, Frémin et Desmar.				
120. —— Duboisii, *Nyst*	.....	.....	*	
121. —— succincta, *Nyst*	.....	.....	*	
122. Actæon (Tornatella) simulatus, *Sow.* (*Brander*)	*	.....	*	*
123. Turbonilla lævissima, *Bosq.*	.....	.....	*	
Tornatella acicula, Nyst, non Desh.				
124. —— spina, *D'Orbigny* (*Desh.*)	.....	.....	*	
125. Pyramidella cancellata, *Nyst*	.....	.....	*	*
126. Niso terebellata, *Bronn*	.....	.....	.....	*
127. Nerita concava, *Nyst* (*Sow.*)	.....	.....	*	
128. Natica glaucinoides, *Sow.*	*	*	*	
129. —— hantoniensis, *Sow.*	.....	.....	*	*
130. —— hemiclausa?, *Sow.*	.....	.....	*	

TABLE IX. (continued).

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower
131. Sigaretus canaliculatus, *Sow.*	.....	.....	.....	•
132. Bulla Sowerbyi, *Nyst*	.....	.....	.....	•
133. —— utricula, *Brocchi*	.....	.....	.....	•
134. —— acuminata, *Brug.*	.....	.....	.....	•
135. —— constricta?, *Sow.*	.....	.....	•	
136. Limneus fabulum?, *Al. Brong.*	.....	.....	•	
137. Planorbis rotundatus?, *Brong.*	.....	.....	•	
P. corneus?, Drap.				
138. —— depressus, *Nyst*	.....	.....	•	
139. Cancellaria elongata, *Nyst*	.....	.....	.....	•
140. —— quadrata, *Sow.*	.....	.....	.....	•
141. —— evulsa, *Sow.* (*Brander*)	•	.....	•	•
142. —— granulata, *Nyst*	.....	.....	•	
143. Turbinella pyruliformis, *Nyst*	.....	.....	.....	•
144. Cordieria Delucii, *Bosq.* (*Nyst*)	.....	.....	.....	•
145. Fusus elongatus, *Nyst*	•	•	•	•
146. —— multisulcatus, *Nyst*	•	.....	•	•
F. trilineatus, Sow.				
147. —— Burdigalensis, *Bosq.* (*Baster.*)	.....	.....	.....	•
148. —— scalariformis, *Nyst*	.....	.....	.....	•
149. —— Deshayesii, *De Kon.*	•	•	•	
150. —— erraticus, *De Kon.*	•			
151. —— Koninckii, *Nyst*	•			
152. —— Waelii, *Nyst*	•			
F. regularis, De Kon.				
153. —— Staquiezii, *Nyst*	•			
F. scalaroides, De Kon.				
154. Pyrula decussata, *Bosq.*	.....	.....	.....	•
P. nexilis, Nyst, non Desh.				
155. —— elegans, *Lamk.*	.....	.....	•	
156. Pleurotoma turbida, *Nyst* (*Brander*)	.....	•	.....	•
157. —— crenata, *Nyst*	•	•	•	
P. subdenticulata, Goldf.				
158. —— Waterkeynii, *Nyst*	•	.....	•	•
159. —— belgica, *Goldf.*	.....	.....	•	
160. —— Bosquetii, *Nyst*	•	.....	•	•
161. —— conoidea, *Nyst* (*Brander*)	.....	.....	.....	•
162. —— Selysii, *De Kon.*	•	.....	.....	•
163. —— Dumontii, *Nyst*	.....	.....	.....	•
164. —— semi-colon?, *Nyst* (*Sow.*)	.....	.....	.....	•
165. —— acuticosta, *Nyst*	.....	.....	.....	•
166. —— costellaria, *Duchast*	.....	.....	•	
167. —— Morrenii, *De Kon.*	•			
168. —— Koninckii, *Nyst*	•			
169. —— flexuosa, *Goldf.*	•	•	•	
P. acuminata, Nyst (non Sow.).				

TABLE IX. (continued).

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower.
170. Cerithium elegans, *Desh.*	.....	.....	*	
C. margaritaceum, Nyst, non Brocchi.				
171. —— subcostellatum, *Schloth.*	.....	.....	*	
C. plicatum, Lamk.				
C. Galeottii, Nyst.				
172. —— incrassatum, *Merian*	.....	.....	*	
C. tricinctum, Nyst.				
173. —— lima, *Desh.*	.....	.....	*	
174. —— Henckeliusii, *Duchast.*	.....	.....	*	
175. Murex Deshayesii, *Duchast*.....	*	*	*	*
176. —— fusiformis, *Nyst*	.....	.....	.....	*
177. —— brevicauda, *Hébert*	.....	.....	.....	*
M. tricarinatus, Nyst.				
178. —— Pauwelsii, *De Kon.*	*			
179. Typhis tubifer, *Montf.*	.....	.....	.....	*
180. —— cuniculosus, *Nyst*	*	*	*	*
T. muticus, Sow.?				
181. Triton argutum, *Brander*	*	*	*	*
T. flandricum, De Kon.				
182. Rostellaria ampla, *Brander*	.....	.....	.....	*
R. macroptera, Lamk.				
183. —— fissurella, *Lamk.*	.....	.....	.....	*
184. —— Sowerbyi, *Mant.*	*	*	*	
Chenopus Sowerbyi, Philippi.				
—— *Margerini*, De Kon.				
185. Cassidaria (Morio) depressa, *V. Buch*	*	*	*	*
186. —— ambigua, *Nyst*	.....	.....	.....	*
187. —— calanthica, *V. Buch*	*			
188. Buccinum Gossardii, *Nyst*	.....	*	*	*
189. —— desertum?, *Brander*.....	.....	.....	*	
190. —— suturosum, *Nyst*	.....	.....	*	
191. Conus Brocchii?, *Bronn*	.....	.....	.....	*
192. —— lineatus?, *Brander*	.....	.....	.....	*
193. Voluta suturalis, *Nyst*	.....	.....	*	*
194. —— cingulata, *Nyst*	.....	.....	.....	*
195. —— Rathieri, *Hébert*	.....	*	*	
V. depressa, Nyst, non Lamk.				
196. —— semigranosa, *Nyst*	.....	.. ...	.....	*
197. —— semiplicata, *Nyst*.....	*	*		
198. Terebellum fusiforme?, *Lamk.*	.....	.....	.....	*
199. Ancillaria canalifera, *Lamk.*.....	.....	.....	.....	*
200. —— buccinoides, *Lamk.*	.....	.....	... ..	*
201. Nautilus ziczac, *Sow.*	*			
Aturia ziczac, Bronn.				
	43	21	106	106

TABLE IX. (continued).

	Limburg Series.			
	Upper.			
	Rupelmonde clay.	Bergh, Nucula loam.	Middle.	Lower.
ANNELIDES.				
Serpula turbinata ?, *Philippi*	.....	.....	.....	•
Galeolaria trochoides, *Nyst*	.....	.....	.....	•
Cyclolites, Nyst.				2
CIRRIPEDA.				
Balanus, sp. non determ.	.....	.....	•	
			1	
ENTOMOSTRACA.				
Cytherella compressa, *Bosq.* (*Münster*)	•	•		
Bairdia punctatella, *Bosq.*	.....	•		
—— marginata, *Bosq.*	.....	•		
—— lithodomoides, *Bosq.*	.....	•		
Cytheridea Mulleri, *Bosq.* (*Münster*)	.....	•	•	
—— papillosa, *Bosq.*	.....	•		
—— Williamsoniana, *Bosq.*	.....	.....	•	
Cythere scrobiculata, *Münster*	.....	•	.....	
—— striato-punctata, *Bosq.* (*Roemer*)	.....	.....	.....	•
—— Jurinei, *Münster*	.....	.....	•	•
—— plicata, *Münster*	.....	•		
—— Nystiana, *Bosq.*	.....	•		
—— Reussiana, *Bosq.*	.....	•		
—— ceratoptera, *Bosq.*	•	•		
—— Lyelliana, *Bosq.*	•			
	3	11	3	2
PISCES.				
Myliobates (Ætobates ?), sp. non determ.	.....	.....	•	
Notidanus primigenius, *Agass.*	•	.....	•	
Galeocerdo minor, *Agass.*	•	.....	•	
Lamna contortidens, *Agass.*	.....	.....	•	
—— cuspidata ?, *Agass.*	•	.....	•	
—— compressa ?, *Agass.*	•			
—— elegans, *Agass.*	•			
Otodus obliquus, *Agass.*	•			
Oxyrhina xiphodon, *Agass.*	•			
—— trigonodon, *Agass.*	•			
—— Desorii ?, *Agass.*	•			
Carcharodon angustidens, *Agass.*	•			
—— heterodon, *Agass.*	•			
	11		5	

Table X.

Showing the Relative Numbers of Species in the different Divisions of the Limburg Tertiary Strata, and the Species common to the several Divisions.

	Upper Limburg.		Middle Limburg.	Lower Limburg.
	A., or Rupelmonde clay.	B., or Nuculaloam of Bergh.		
Total number of species of Mollusca	43	21	106	106
Species peculiar	20	1	65	68

Species common to	A. and B.	A. and Middle.	B. and Middle.	A. and Lower.	B. and Lower.	Upper and Middle.	Upper and Lower.	Middle and Lower.
	12	19	16	17	12	25	22	33

Table XI.

Fossils common to the Limburg Beds and to English Eocene Strata.

(U. M. and L. indicate Upper, Middle, and Lower Limburg.)

	Limburg Divisions.	British and other Localities.
1. Clavagella tibialis?	L.	Calcaire grossier.
Leguminaria papyracea	L.	Calcaire grossier.
Solecurtus compressus	M. L.	Upper Marine, Barton, Bracklesham.
Mya angustata?	M.	Upper Marine, Isle of Wight.
5. Lutraria oblata?	U.	Pegwell Bay; Herne Bay; Bognor.
Corbula pisum	U. M. L.	Barton; Brackleaham.
—— striata	M. L.	Barton.
Psammobia rudis	M.	Barton; Calc. gross.
Lucina Thierensii	M.	Upper Marine, Hants.
10. Diplodonta apicalis	L.	Barton (species very near, if not identical—*Morris*).
Axinus Nystii	U. M. L.	Lond. Clay proper, Highgate.
Cyrena semistriata	M.	Upper Marine, Isle of Wight.
Venus lævigata	M. L.	Barton; Calc. gross.
—— sulcataria	U. L.	Bracklesham (Messrs. Morris and Edwards find no difference in the species).
15. —— incrassata and varieties	U. M. L.	Upper Marine, Hants.

TABLE XI. (continued).

		Limburg Divisions.	British and other Localities.
	Venus Kickxii	M.	Barton?
	Cardium hippopæum	L.	Bracklesham; Calc. grosa.
	—— porulosum	L.	Bracklesham.
	Cypricardia pectinifera	L.	Barton.
20.	Cardita Kickxii?	U.	Barton.
	Nucula similis	L.	Barton; Highgate.
	Limopsis scalaris	L.	Barton.
	Pectunculus fossilis	M.	Bracklesham.
	Mytilus Faujasii	M.	Upper Marine.
25.	—— corrugatus?	M.	Vicentine, Eocene.
	Dreissena Basteroti	M.	Upper Marine.
	Pinna affinis?	L.	Bognor; Highgate.
	Pecten reconditus	L.	Barton.
	—— corneus	L.	Bracklesham.
30.	Ostrea cariosa	L.	Calc. grosa.
	—— gigantea	M.	Barton.
	—— bellovacina?	M.	Woolwich; Lower tertiaries.
	Capulus cornucopiæ	M. L.	Bracklesham; Calc. grosa.
	Infundibulum lævigatum	M.	Calc. grosa.
35.	Phorus extensus	L.	Barton; Calc. grosa.
	Ampullaria mutabilis	M. L.	Barton and Upper Marine.
	Paludestrina Draparnaudii	M.	Upper Marine, Hants.
	—— pupa	M.	Upper Marine.
	Rissoina Nystii	M.	Upper Marine, Hants.
40.	Rissoa? Chastelii	M.	Upper Marine, Hants.
	Actæon simulatus	U. M. L.	Barton; Highgate.
	Turbonilla spina	M.	Calc. grosa.
	Niso terebellata	L.	Bracklesham.
	Nerita concava	M.	Up. Mar., Hants; Calc. grosa.
45.	Natica glaucinoides	U. M.	Barton; Bracklesham.
	—— hantoniensis	M. L.	Barton; Bracklesham.
	Sigaretus canaliculatus	L.	Barton.
	Bulla acuminata	L.	Barton.
	—— constricta	M.	Barton; Calc. grosa.
50.	Limneus fabulum	M.	Freshwater, Isle of Wight.
	Planorbis rotundatus	M.	Freshwater, Isle of Wight.
	Cancellaria evulsa	U. M. L.	Barton; Calc. grosa.
	—— quadrata	M.	Barton.
	Fusus multisulcatus	U. M. L.	Highgate?; Calc. grosa.?
55.	—— scalariformis	L.	Barton.
	Pyrula elegans	M.	Calc. grosa.
	Pleurotoma turbida	U. L.	Barton.
	—— flexuosa	U. M.	Barton.
	—— crenata	U. M.	Barton.
60.	—— Selysii	U. L.	Highgate.
	—— semicolon?	L.	Barton; Highgate.
	—— conoidea	L.	Barton.
	Cerithium elegans	M.	Barton.
	—— lima	M.	Upper Marine.
65.	—— plicatum	M.	Upper Marine.
	—— incrassatum	M.	Upper Marine, Hants.

TABLE XI. (continued).

		Limburg Divisions.	British and other Localities.
	Typhis cuniculosus	U. M. L.	Barton?
	Triton argutum	U. M. L.	Barton, Highgate.
	Rostellaria ampla	L.	Barton.
70.	—— fissurella	L.	Barton; Calc. gross.
	—— Sowerbyi	U. M.	Highgate.
	Cassidaria ambigua	L.	Barton.
	Buccinum Gossardii	U. M. L.	Barton.
	—— desertum	M.	Barton.
75.	—— suturosum	M.	Barton.
	Conus lineatus?	L.	Barton.
	Terebellum fusiforme?	L.	Barton; Bracklesham.
	Ancillaria canalifera	L.	Barton.
	—— buccinoides	L.	Barton; Calc. gross.
80.	Nautilus ziczac	U.	Highgate; Sheppey.

7. *Nomenclature of the Limburg Tertiary Strata; and whether they should be referred to the Upper Eocene or Lower Miocene periods.*

My original reasons for not classifying the upper marine strata of the Paris basin, commonly called "sables de Fontainebleau," &c., and the upper marine and freshwater of the Isle of Wight as Miocene, were threefold.

1st. Because many of the shells were identical with fossils from the Calcaire grossier, Barton clay, and other Eocene beds, while the general aspect of the fauna resembled that of the lower, rather than of the upper tertiary strata.

2ndly. Because of the great distinctness of the fauna from that of the faluns of Touraine, which contained above 300 species of shells, and which I had chosen as the type of the Miocene period.

3rdly. Because the proportion of recent species did not appear to be sensibly greater than in the Eocene strata, regarded as a whole.

Geologists will be enabled by means of the Tables given above to appreciate the true merits of this question. It will be seen that out of 201 species of Limburg mollusca, eighty are identical with fossils commonly regarded by English geologists as Eocene. Even if we omit seventeen species which occur, fifteen of them in the upper marine of Hampshire, and two in the associated freshwater beds, still we have sixty-three Eocene species in a list of 201. Ten of these identifications, however, are given doubtfully, because the means of comparison were more or less deficient. If we exclude all these, we have still fifty-three remaining. I am, however, by no means disposed to exclude the Upper Marine of Hampshire from the Eocene period, as the number of species common to it and to the Barton beds is shown by old and modern researches, especially by Dr. Wright*, to be considerable.

* Proceedings of the Cotswold Naturalists' Club for 1850, p. 87 *et seq.*; and Ann. and Mag. N. Hist. 2 ser. vol. vii. p. 14 *et seq.*

If we next turn to the fifty-two Upper Limburg species (Table X.), it will be seen that nineteen are identified with English Eocene fossils, one only of the number (*Venus incrassata*) being admitted on the disputed ground of its occurring in beds so modern as the Upper Marine of Hampshire. In regard to two of the species also, we require fuller information before we can feel sure of their agreement.

Out of 106 Middle Limburg species, forty-eight are British Eocene, but thirteen of these must be deducted by those who do not consider the upper marine and the freshwater beds of Hampshire as Eocene. Even after this deduction, together with two others as doubtful, nearly a third of the whole are common to undoubted Eocene beds.

Lastly, out of 106 Lower Limburg fossils, forty-four are British (or well-known French) Eocene shells, and only one of these (*Venus incrassata*) would have to be excluded as occurring only in the Upper Marine of Hants. If we omit five others as doubtful, for want of ample means of comparison, there remain thirty-eight Eocene species, or more than a third. This is as great a resemblance as can usually be affirmed of any one of the great members of the English or French Eocene divisions, when compared with another,—the Barton beds, for example, with the Highgate, or the Calcaire grossier with the Sables inférieurs Soissonnais.

It is natural to find a larger proportion of shells in the Lower Limburg, than in the Upper, common to the older Eocene. Among the nineteen shells of the latter identified with Eocene species, eleven occur in the Barton clay, or high up in the English series. When in the 'Principles of Geology' I placed the Mayence basin in the Miocene division, my classification was in that respect inconsistent with itself, for M. de Koninck pointed out to me in 1850 his reasons for concluding, many years before, that a great many of the Mayence fossils agreed with the Limburg and Rupelmonde strata*. M. Bosquet has since observed to me, that it is with the Middle, and not with the Lower Limburg division, that this analogy with the Mayence basins holds good.

In the paper by M. Hébert before referred to†, it will be seen that he enumerates twenty-four species of shells from the "Ostrea cyathula clay" and "Sables de Fontainebleau," &c., at Paris, Etampes, and other places in France, as decidedly identical with Limburg and Rupelmonde fossils. All of these are found in the Middle or Upper Limburg beds, and only nine in the Lower Limburg. This greater agreement with the former arises partly from the presence of freshwater species, none of which occur in the Lower Limburg. Of the twenty-four French species, four are common to the Rupelmonde Clay (or 4 in 43), and nine to the Lower Limburg beds (or 9 in 106); so that the relationship of the French fossils, taken as a whole, with the highest and lowest divisions of the Belgian formations, which are both of them marine, do not seem to differ essentially.

I have met with no Nummulites in any of the Belgian Upper

* See 'Manual of Geology,' 1851, p. 177; where I alluded to the agreement of the Belgian and Mayence beds with those of Hermsdorf near Berlin.

† Bulletin de la Soc. Géol. de France, t. vi. p. 459. 1849.

Eocene strata, whether at Rupelmondè or Kleyn Spawen. In that country, as in England and France, they seem to characterize the Middle Eocene series, and not to occur in the Upper or Lower Eocene; a result corresponding to that at which M. d'Archiac had previously arrived in France.

The proportion of recent species in the 201 fossil Mollusca of the Limburg beds has still to be considered. I may safely affirm that it is not greater than in older or universally acknowledged Eocene formations. The following fossils have been supposed to agree with living shells:—

1. Cyprina islandica ?, var.
2. Rissoina Nystii.
3. Rissoa violacea ?
   R. plicata.
4. Planorbis corneus ?
   P. rotundatus ?
5. Limneus fabulum ?
6. Solen ensis, var. ?
7. Ostrea cochlear.

Judging from one valve of the *Cyprina* above mentioned, given to me by M. Bosquet, Professor Forbes believes the shell to differ from the living species; the muscular impression being larger, and the pallial impression not similar. *Rissoa plicata*, Desh., appeared to M. Bosquet to agree perfectly with *R. violacea*, Frem. and Desm., a Mediterranean shell, but Prof. E. Forbes, after carefully comparing them, is not satisfied with the identification; and he remarks, in regard to the genera *Rissoina* and *Rissoa*, that there is so great a want of unanimity among the best naturalists as to the value of the specific characters of some of the commonest living species, such as *Rissoa balthica*, that it would be dangerous to attempt to identify fossils in these genera with living molluscs, when they occur as members of a fauna decidedly extinct. The same remark will apply to *Limneus*, *Planorbis*, and *Ostrea*. I do not possess the means of comparing the *Solen* alluded to by M. Nyst. Two or three of the Entomostraca, as *Bairdia lithodomoides* and *Cytheridea Mulleri*, are pronounced, on the high authority of M. Bosquet, to be quite undistinguishable from living species. Such identifications do not affect the data on which my original nomenclature of tertiary classification was founded, as I confined myself exclusively to the fossil mollusca.

With regard to the faluns of Touraine, although containing more than 300 species of shells, there are scarcely any species identical with those of the Limburg; so that the greater analogy of these last with the Eocene type, than with that which I have always considered as Miocene, is striking.

§ 7. *On the Middle Eocene Strata of Belgium and French Flanders, or the "Nummulitic Eocene"* (E. 1, 2, 3, Table I. p. 279). *Systèmes Laekenien, Bruxellien et Ypresien, étage supérieur*, of M. Dumont.

The group of tertiary strata which we meet with next in the descending order in Belgium (comprising the "Systèmes Laekenien, Bruxellien et Ypresien" of M. Dumont) corresponds most nearly, if

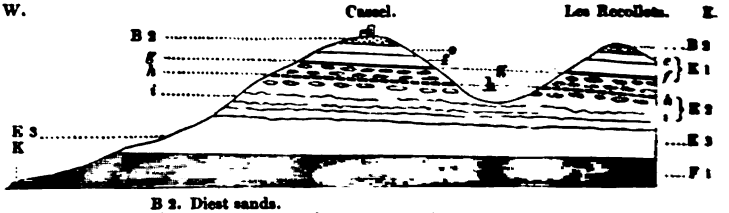
not entirely, in age with the Barton, Bagshot, and Bracklesham beds of the London and Hampshire basins, and with the *Sables moyens*, *Calcaire grossier*, and part of the *Sables inférieurs* of the Parisian series. The two districts where I studied them principally were the neighbourhood of Brussels and that of Cassel, in French Flanders.

1. *Eocene Tertiary Strata of Cassel, near Dunkirk. Hill of Cassel, Mont Noir, and Hill of Boeschepe.*

I shall first describe the Cassel district, because some of the Eocene strata there occupy a somewhat higher position than any fossiliferous strata older than the Limburg series known at present in other parts of French Flanders and Belgium.

The town of Cassel, situated about twenty miles S.S.E. of Dunkirk (see Map, Pl. XVII.), stands on the summit of a hill, 515 English feet (157 metres) above the level of the sea. This hill rises on its north, south, and west sides very abruptly from the surrounding plain, which is about 400 feet below the level of the top of the hill. The railway-station (K. fig. 4), at the western base of the hill, has been ascertained to be 40 metres (131 English feet) above the sea. The Hill of Cassel is the most western of a small chain which extends ten or twelve miles in a south-easterly direction into Belgium, the town of Ypres being situated near its eastern extremity. These hills are all of very similar composition, geologically speaking, although the Hill of Cassel displays, upon the whole, the greatest number of well-characterized subdivisions of the tertiary series. It will be useful therefore to consider it as a type, and to compare the others with it.

Fig. 4.—*Section of the Hill of Cassel.*



B 2. Diest sands.
E 1. (Laeken beds). *c*. Ferruginous sands (upper part of E 1 ?). *f*. Sandy glauconite (middle part of E 1 ?). *g*. "Black band," with *Num. variolarius*.
E 2. (Brussels beds). *h*. *Num. laevigatus* bed. *i*. Green marls and underlying sands, with *Num. laevigatus*.
E 3. Sands, clays, &c. Lower Nummulitic ?
F 1. London Clay with septaria. Bored to a depth of 320 feet.
K. Cassel railway-station.

This hill, like all the others, is capped with ferruginous sands and sandstone, doubtlessly belonging to the Diest sands (B. 2. Table I. p. 279 and fig. 4), as usual barren of fossils. Their thickness at Cassel cannot be measured, but on the summit of the hill of Mont Noir, near Bailleul, about fourteen miles to the south-east (see Map, Pl. XVII. fig. 1), this formation is seen to be 20 feet thick. In that hill, which is 430 feet above the level of the sea, the Diest sands consist, at their base, of a conglomerate of flint-pebbles coated with hydrate of

iron. In the sands above this conglomerate are many geodes and large hollow pipe-like concretions of hydrate of iron. Below are ochreous, yellow, ferruginous sands (*e*), which M. Meugy, adopting the opinion of M. Dumont, has called "Tongrian" in his map of French Flanders, thereby implying that they belong to the Limburg or Upper Eocene series described above, § 6. They are about 50 feet thick in Mont Noir (where they are far better exposed to view than at *e*, fig. 4, in the Hill of Cassel), and at the depth of 30 feet from the top contain an irregular and discontinuous bed of rolled chalk-flints, some of them large, or from 4 to 8 inches in diameter. Ferruginous sands are seen above and below the gravel. In some of those immediately below it are casts of shells, to which my attention was first called by M. Meugy, and of which many were collected for me by M. Curtel, a French engineer, with whom I explored the hill.

Fossil Shells of the Ferruginous Sands next below the Diest Sands in Mont Noir near Cassel.

1. Corbula gallica, *Lamk.*
2. ——, another species.
3. Thracia?
4. Sanguinolaria Hollowaysii, *Sow.*
5. Tellina.
6. Lucina divaricata?, *Lamk.*
7. Cytherea suberycinoides, *Desh.*
8. ——, another species.
9. Cardium porulosum, *Brander.*
10. —— semigranulatum, *Sow.*
11. —— turgidum, *Brander.*
12. Pecten reconditus, *Brander*, sp.
13. Ostrea inflata, *Desh.*
14. Dentalium strangulatum, *Desh.* *Ditrupa?*
15. Natica sigaretina, *Lamk.*
16. —— patula, *Desh.*
17. —— ambulacrum, *Sow.* sp.
18. Turritella imbricataria, *Lamk.*
19. Buccinum junceum, *Sow.*
20. Voluta.
21. Conus antediluvianus?, *Lamk.*

The *Sanguinolaria Hollowaysii* is a well-known English species, occurring at Bracklesham, and the whole list is such as we might meet with in the Upper Bagshot Sands, to which these beds bear a considerable mineralogical resemblance. The absence of all fossils peculiar to the Limburg series, both here and in the Cassel chain of hills generally, makes me question the propriety of referring these sands to the "Tongrian" beds of Dumont. The casts of *Ostrea inflata* are numerous, and this fossil abounds at Cassel, as we shall presently see, in beds (lower in the series) which contain *Nummulites variolarius* in profusion. At Mont Noir the section below the ferruginous sands is imperfectly seen or barren of fossils, but in the neighbouring hill of Boeschepe, to the westward, the same yellow irony sands as those of Mont Noir recur, with some white and green sands associated, beneath which are grey, bluish, and greenish sands, 20 feet thick, with thin layers of clay, and a fossiliferous glauconite, which I shall now describe.

The glauconite alluded to is only 6 inches thick. It contains coarse grains of blackish green earth, and is without calcareous matter. It was laid open in a cutting, at the time of my visit, for a road which runs south and north from the village of Berthen to Boeschepe (see Map, Pl. XVII. fig. 1). Casts of the following fossil shells occurred in the glauconite, only a few feet below the level of the watershed of the ridge, and on its northern side.

Shells of the Glauconite of the Hill of Boeschepe near Cassel.

1. Crassatella plicata?, *Sow.*
2. Lucina squamula, *Desh.*
3. Cytherea or Venus.
4. Cardium porulosum, *Brander.*
5. ——, with fine striæ.
6. ——, third species.
7. Cardita acuticostata?, *Lamk.*
8. Arca barbatula, *Lamk.*
9. Mytilus acutangulus, *Desh.*
10. Mytilus, another species.
11. Ostrea flabellula?, *Lamk.*
12. Fusus or Murex?; allied to *M. frondosus* or *M. cornutus.*
13. Cassidaria carinata?, *Lamk.*
14. Voluta digitalina?, *Lamk.*
15. Cypræa; cast, allied to *C. inflata*, Lamk.
16. Ovula; of very large size.

Cardium porulosum, an *Ostrea* (probably *O. flabellula*), and a *Mytilus*, are the most common among the casts. The most striking fossil, however, was one discovered here by M. Curtel, and now in the collection of M. Meugy at Lille. It is an *Ovula* of the size of *Cypræa Coombii*, Dixon, 'Foss. Suss.' pl. 8. fig. 6, or of *Ovula tuberculosa*, Desh. 'Coq. Foss. de Paris,' pl. 97. fig. 17. On my showing the cast, however, to M. Deshayes, he pronounced it to be different, and to agree with an unpublished shell, of which he possesses imperfect remains from a bed of the *Calcaire grossier* at Chaumont in France, overlying strata containing *Cerithium giganteum*.

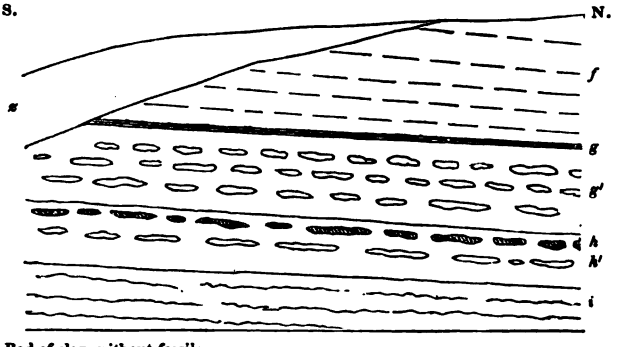
As the Boeschepe glauconite succeeds immediately to the ferruginous sands, and, according to M. Curtel, occurs at the height of 112 metres above the sea (only 12 metres below the summit of the hill of Boeschepe), I am inclined to identify it with a similar glauconite found at Cassel (at *f*, fig. 4) above the "bande noire" (*g*, fig. 4), afterwards to be mentioned; but, as the nummulitic beds of Cassel have not yet been observed in the hills of Boeschepe or Mont Noir, I cannot decide with confidence on its exact position.

We may now return to the Hill of Cassel, which, as before stated, is capped by the Diest sands (B 2, fig. 4), under which are other ferruginous strata (*e*, fig. 4), as yet unproductive of fossils, but which I believe to be of the same age as the Mont Noir beds already described. M. Meugy estimates the united thickness of these sands, B 2, and *f*, fig. 4, at 56 feet. Their junction with the beds next below is not seen, but on the eastern slope of the hill, which faces the Mont des Recollets, a section is laid open in an excavation for stone and sand, called Caton's Pit from the person who now works it, which may be regarded as exhibiting the continuation of the series. The mass of clay without fossils on the left side of this section (*z*, fig. 5) is unconformable, as here represented. It is of considerable thickness, perhaps 20 to 30 feet; but neither could I, nor M. Meugy who examined it with me, determine its true age.

(1.) The bed *f*, figs. 4 & 5, is 34 feet thick, and consists of a sandy glauconite with some thin layers of clay in its lower portion. In parts it is spotted with yellow; in other beds it contains coarse blackish-green grains like those of the glauconite of Boeschepe, and, as in that hill, impressions of shells occur, the calcareous matter of the shell having wholly disappeared. The only recognizable species were *Pecten corneus* and *Cardium semigranulatum*. The general dip of these strata

and of those immediately subjacent is at a slight angle towards the north-east.

Fig. 5.—*Section in Caton's Pit, on the eastern slope of the Hill of Cassel.*



e. Bed of clay, without fossils.
f. Sandy glauconite (1).
g. "Black band" with *Ostrea inflata* and *Num. variolarius* (2).
g'. Sands with *Nipadites*, *Nautilus*, *Cerithium giganteum*, *Num. variolarius*, &c. (3 to 6).
h. Green sand and sand-rock with *Num. lævigatus* (7).
h'. Sands and sandstone with *Ostreæ*, &c. (8 to 10).
i. Green marls (11).

(2.) Next below is a dark bed, called by the workmen *la bande noire* (*g*, figs. 4 and 5), 1½ foot thick. It is divided in some places by thin layers of yellow sand, in which I found the following fossils:

Shells of the "Bande noire," Cassel (*g*, figs. 4 & 5).

Nummulites variolarius, *Lamk.*
Cryptodon?
Venus; small.
Cardita.
Nucula margaritacea, *Lamk.*
Pecten imbricatus? *Desh.*
Pecten plebeius, *Lamk.*
Anomia lævigata, *Sow.*
Ostrea inflata, *Desh.*
Dentalium strangulatum, *Desh.*
Natica.
Turritella.

The presence of *Nummulites variolarius* and *Ostrea inflata* indicates the commencement of those Eocene strata which are called at Brussels the "Laeken beds," and to a higher division of which those sands in the Cassel hills, which have been hitherto called "Tongrian," may perhaps belong.

(3.) Immediately below the *bande noire* are beds of yellowish sand with green grains, 9 feet thick. Within a foot of the top of this mass is an irregular layer of sandstone, or a bed of nodules of sand cemented by calcareous matter, in which many of the following fossils occur in the state of casts, while the rest are free in the sand.

Nummulites variolarius, *Lamk.*; very abundant.
Turbinolia sulcata, *Lamk.*
T. Nystiana? Haime.
Lunulites radiatus, *Lamk.*
Clavagella coronata, *Desh.*
Teredina.
Corbula pisum, *Sow.*
Tellina rostralis, *Lamk.*
Lucina (Loripes) divaricata, *Lamk.*
Venus; the same as one found at Laeken.
Venus elegans? *Sow.*
Cytherea suberycinoides, *Desh.*

Cypricardia pectinifera, *Morris.*
Cardium semigranulatum, *Sow.*
—— obliquum, *Desh.*
Cardita elegans, *Lamk.*
Nucula (Leda) Galeottiana, *Nyst.*
Pecten plebeius, *Lamk.*
Ostrea inflata, *Desh.*
Dentalium strangulatum, *Desh.*
Turritella imbricataria (young)? *Lamk.*
Myliobates.
Nipadites Burtini; drilled by *Teredinæ.*

In a sandstone cast of *Nipadites* (once regarded as a cocoa-nut by Burtin) which retains perfectly its shape, we see the tubes of *Teredinæ* in great numbers, these mollusks having evidently drilled the husk of the floating fruit through and through. The occurrence of two specimens of this fossil in this bed, with *Nummulites variolarius, Tellina rostralis, Cypricardia pectinifera,* and other Laeken shells, shows that the plant is referable here to a higher part of the series than that in which it is found in the environs of Brussels, which, as we shall afterwards see, is below the level of the *Nummulites lævigatus.* In the Sheppey clay the same *Nipadites* is seen to range still lower in the Eocene series.

That these fruits were drifted down to the sea is shown by their being perforated by *Teredinæ,* and I am informed by Dr. Hooker that no fruits are so often met with floating down the arms of the Ganges, in the delta near the sea, as those of *Nipa fruticans.* They are often so abundant that the paddle-wheels of steamboats are obstructed by them.

(4.) Next below is a bed of whitish and yellow sand, 3½ feet thick, containing in its upper part a bed of concretions of sandstone about 10 inches thick. The fossils are—

Nummulites variolarius, *Lamk.*
Lunulites radiatus, *Lamk.*
Tellina sinuata? *Lamk.*
Lucina.
Solarium (Vermetus) Nystii, *Gal.*

(5.) "Nautilus-bed," 3½ feet thick. Grey and yellow sand, with a bed of soft sandstone in nodules in the upper part, 1 foot thick, containing

Lucina (Loripes) divaricata, *Lamk.*
Pecten scabriusculus, *Math.*
—— plebeius, *Lamk.*
Anomia lævigata, *Sow.*
Turritella.
Nautilus Burtini, *Gal.*
Crab's claw.
Vertebræ and teeth of Lamna.

No less than four specimens of *Nautilus,* all perfect, though in a decomposing state, were dug out of the bed when I was present. One variety resembles *N. imperialis* in general form, but seems to be the same species as *N. Burtini.*

(6.) "*Cerithium giganteum* bed;" thickness 1 foot 8 inches. Yellowish sand with grains of green earth, and containing in its upper part an irregular bed of shelly sandstone, one foot thick; both in the loose sand and in the stone rolled pebbles of chalk-flints occasionally occur. The fossils are—

Nummulites variolarius, *Lamk.*
Lunulites radiatus, *Lamk.*
Turbinolia sulcata, *Lamk.*
T. Nystiana? Haime.
Lucina mutabilis, *Lamk.*
—— contorta? *Def.*
—— divaricata, *Lamk.*
Cytherea lævigata, *Lamk.*
Cardita elegans, *Lamk.*
Nucula margaritacea, *Lamk.*
—— striata, *Lamk.*
Pecten scabriusculus, *Math.*
—— plebeius, *Lamk.*
—— corneus, *Sow.*
Ostrea flabellula, *Lamk.*
—— virgata, *Goldf.*

Terebratula Kickxii, *Gal.*
Solarium (Vermetus) Nystii, *Gal.*
Turritella edita, *Sow.*; very abundant.
Cerithium giganteum, *Lamk.*; abundant.
Cassidaria nodosa, *Nyst.*
—— carinata, *Lamk.*
Nautilus Burtini, *Gal.*
Echinolampas Galeottianus, *E. Forbes*; abundant in lower part of bed.
—— affinis ?, *E. Forbes.*
Clypeaster affinis ?, Goldf.
Crab's claw.
Vertebræ and teeth of Lamna.
Myliobates.

In the highest part of the bed, above the nodules of stone, *Cerithium giganteum* occurs in great numbers with *Turritella edita*. *Nummulites variolarius* is seen in the sand filling the interior of the *Cerithia*. *Nummulites lævigatus* occurs, so far as I observed it, below the stony bed, and marks the beginning of the beds where that larger species abounds, although at the contact both might possibly be detected in the same stratum. The *Cerithium giganteum* bed is probably about the level of the line of junction of the "Laeken" and "Brussels" Middle Eocene divisions hereafter to be described in the environs of Brussels.

(7.) "*Nummulites lævigatus* bed" (*h*, figs. 4 & 5); thickness 1½ foot. This bed consists in parts of a hard greenish sand-rock, containing *Nummulites lævigatus* and *N. scaber*, and partly of incoherent sand with green grains, with the same species of *Nummulites* loose and disseminated. The molluscs mentioned in the following list occur both in casts and as shells in the sand. The teeth of Sharks are numerous.

Nummulites lævigatus, *Brug.*; very abundant.
—— scaber, *Lamk.*; very abundant.
Gastrochæna.
Crassatella.
Cytherea lævigata, *Lamk.*
Lucina mutabilis, *Lamk.*
Cardium semigranulatum, *Sow.*
—— porulosum, *Brander.*
Cardita planicostata, *Lamk.*
Pectunculus.
Nucula Galeottiana, *Nyst.*
Ostrea flabellula, *Lamk.*
—— virgata, *Goldf.*
—— cymbula, *Lamk.*
Terebratula Kickxii, *Nyst.*
Natica; two species.
Turritella imbricataria, *Lamk.*
Asterias (Goniaster) poritoides ?, *Desm.*; marginal ossicles.
Echinolampas Galeottianus, *E. Forbes.*
Lamna elegans, *Agass.*
Otodus macrotus, *Agass.*
Myliobates.

Prof. E. Forbes, on my explaining to him the relative abundance of the shells in this and most of the incumbent beds at Cassel, is of opinion that they were probably deposited in a depth of about 15 fathoms, or at the lowest part of his "perilittoral zone."

(8.) "Oyster-bed;" thickness 5 feet. Yellowish and greenish-grey sand, with great numbers of *Ostreæ* (*O. flabellula*) dispersed through it.

(9.) Bed of hard sandstone with calcareous cement; thickness 1 foot 6 inches; containing

Nummulites scaber, *Lamk.*
Corbula gallica, *Lamk.*
Thracia.
Mactra semisulcata, *Lamk.*
Tellina.
Cytherea lævigata, *Lamk.*
Lucina (Loripes) divaricata, *Lamk.*
Cardium; like *C. discors*, Lamk.
Cardium porulosum, *Brander.*
Cardita planicostata, *Lamk.*
Pectunculus.
Ostrea flabellula, *Lamk.*
Dentalium strangulatum, *Desh.*
Stomatia.
Melania marginata, *Lamk.*
Fusus bulbiformis, *Lamk.*
Buccinum stromboides, *Herm.*
Rostellaria fissurella, *Lamk.*
—— macroptera, *Lamk.*
Conus deperditus (young) ?, *Brug.*
Terebellum.
Asterias.

(10.) "White sands;" with three or four layers of stone similar to those above described, each 8 or 10 inches in thickness, with few casts of shells, one of them a cast of *Lucina divaricata*. Some of the sand snow-white; the lower 8 feet, in which the sand is whitest, not exposed, but pierced by boring.

(11.) "Green marls" (*i*, figs. 4 & 5); thickness 12 feet. Here the continuous section ceases, but I have no doubt that the green marls and glauconite seen at a lower level immediately to the north (in an adjoining deep lane, at the distance of a few hundred yards only), and similar beds occurring to the eastward (in the road leading up the slope of the Mont des Recollets), are next in the descending order. Some of this coarse-grained sandy glauconite is very dark-coloured, and in parts very calcareous. I obtained from it the following fossils:

Turbinolia sulcata, *Lamk.*
Cytherea lævigata, *Lamk.*
—— suberycinoides? *Desh.*
Cardium porulosum, *Brander.*
——, another species.
Cardita decussata, *Lamk.*
Pectunculus.
Ostrea virgata, *Goldf.*
—— flabellula, *Lamk.*
Dentalium.
Bifrontia serrata, *Desh.*
Turritella multisulcata, *Lamk.*, or intermedia? *Desh.*
—— imbricataria, *Lamk.*
Sigaretus canaliculatus, *Sow.*
Natica parisiensis, *D'Orb.*
Pleurotoma.

Between the green fossiliferous marls last mentioned (*i*, figs. 4 and 5) and the upper part of the Mont des Recollets, where there is a large deserted quarry on the western brow of the hill, we may trace in the ascending order nearly all the beds already described, from *i*, figs. 4 and 5, to the *Bande noire*. Several of the stony concretionary sandstones are visible, and, overlying these, the *Bande noire* itself, with *Ostrea inflata* and *Nummulites variolarius*, is very conspicuous. Above the whole appear the glauconiferous and ferruginous beds considered as "Tongrian" by MM. Dumont and Meugy, *e*, fig. 4, and the Diest sand, B 2.

There is a large sand-pit at the south-eastern base of the Hill of Cassel, belonging to M. Planque, at a somewhat lower level than the green marls (*i*) already described, where a vertical section of sands 50 feet thick is laid open. Here several oblique shifts occur, intersecting the beds at a high angle, one of which has thrown down some of the strata as much as 12 feet perpendicularly. At the top of the pit are greenish and yellow sands without fossils. Lower down there are from 35 to 40 feet of white and yellow sands; and in some seams of the yellow sands stained with ferruginous matter, I found numerous specimens of *Nummulites lævigatus* and *N. scaber* in a very decomposed state, so that M. d'Archiac had much difficulty in identifying the species. Lastly, at the bottom of the whole is a white sand, 5 feet thick, passing occasionally into a sandstone with casts of shells, below which dark green sands and glauconite have been pierced in boring. The absence of the five or six stony beds, *g'* and *h'*, fig. 5, in these white sands of M. Planque's quarry makes it difficult to imagine that we have here the representatives of the same series as in Caton's pit; the difference of level would not of itself be a valid ar-

gument to prove their greater antiquity, because a fault may have thrown them down. I am rather of opinion that the beds of the quarry are older than the green marls or shelly glauconite, *i*, figs. 4 and 5.

The following are the fossils found by me in the sandstone :—

Fossils of the Sand-pit at the south-east base of the Hill of Cassel, or Planque's quarry.

Lunulites.
Solen.
Panopæa intermedia ?, *Sow.*
Corbula.
Mactra semisulcata ? *Lamk.*
Lucina divaricata, *Lamk.*
—— mutabilis, *Lamk.*
Cytherea lævigata, *Lamk.*
——; allied to *C. nitidula*, Lamk.
Cardium porulosum, *Brander.*
——; like *C. discors*, Lamk.
Cardita planicostata, *Lamk.*
Nucula margaritacea, *Lamk.*
Pectunculus; large species.
Limopsis ?
Ostrea flabellula, *Lamk.*
Ostrea cymbula, *Lamk.*
Vermetus Bognorensis?, *Sow.*, or Nystii?
Trochus agglutinans, *Lamk.*
Phorus Parisiensis, D'Orb.
Turritella.
Natica patula, *Desh.*
Bulla ?
Fusus.
Rostellaria macroptera, *Lamk.*
Voluta, two species.
Terebellum (Seraphs) convolutum, *Lamk.*
Lenita patelloides, *E. Forbes.*
Nucleolites patelloides, Galeotti.
Asterias.
Myliobates.
Lamna.

These fossils show clearly that we have here such an assemblage as belongs to the beds which in England and France contain *Nummulites lævigatus.*

After examining the numerous sections exposed in other parts of the Hill of Cassel, I could find no *fossiliferous* strata older than those above enumerated. Next to the sands already mentioned are green and yellowish sands and clays, which form the upper part of the *Système Ypresien* of Dumont, but in which I could not detect the usual fossil, *Nummulites planulatus.*

Still lower, a vast thickness of brown clay (F 1, fig. 4), corresponding to the London Clay, has been bored at the railway station to the depth of 100 metres, or 320 English feet, without the bottom being reached.

In naming the above fossils of Cassel, a great part of which are unfortunately in the state of casts, I had the advantage of M. Nyst's assistance, whose collection of Belgian species is most extensive and whose palæontological skill is well known. In comparing them since with British fossils, I have been assisted by Mr. Morris. A general list of the whole is given in Table XIII. p. 351, where two columns are devoted to them, entitled "Upper" and "Lower." The "Upper" column refers to those shells of the Hills of Mont Noir and Cassel which belong to strata decidedly above the "*Nummulites lævigatus* bed." The "Lower" refers to the Cassel shells which belong to the bed last mentioned, and to the other fossiliferous strata of sand and green marls above enumerated as occurring in the Hill of Cassel.

I have omitted the Boeschepe shells in Table XIII., as their position was not positively ascertained, although, for reasons before stated, I should place them in the "Upper" column.

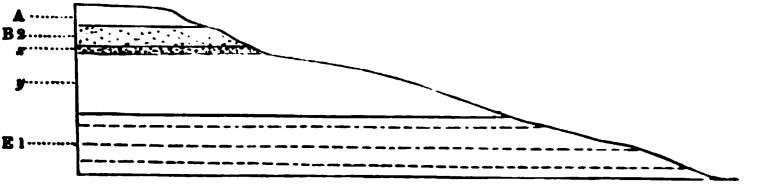
2. *Middle Eocene Strata of Brussels.*

[1.] *Laeken beds. Dileghem, Jette, Laeken, &c.*

I shall now pass to the neighbourhood of Brussels, the most important of the districts after Cassel, where I had an opportunity of studying the Middle Eocene strata. The capital of Belgium is distant from Cassel about seventy-five English miles, in a straight line due east. In exploring its environs I had the great advantage of being accompanied by my friend Captain Le Hon, who had made a fine collection of tertiary fossils, and whose accurate knowledge of palæontology enabled him to render me the greatest assistance. We visited together most of the localities which I shall have to mention. M. Déby also of Brussels accompanied us in many of our excursions, and gave us much information respecting the geological structure of the country.

The general level above the sea of the higher grounds or table-lands round Brussels is about 300 feet, the valleys which intersect them cutting to the depth of 200 feet and upwards, so as to descend to within 60 and 70 feet of the sea-level. On the highest grounds, and at many intervening elevations, loess is found (see Section, fig. 6).

Fig. 6.—*Section near Dileghem, two miles N.N.W. of Brussels.*



A. Loess.
B 2. Diest sands.
x. Bed of rolled flint-pebbles.
y. Yellow and green sands.
E 1. Laeken beds.

Thus, near Dileghem, two miles N.N.W. of Brussels (Map, fig. 3, Pl. XVII.), it may be seen crowning the elevated platform (fig. 6, A). Next in order iron-sandstone and green sands, exactly resembling those of Diest (B. 2. fig. 6), about 10 feet thick, below which is a bed of well-rolled flint-pebbles (*x*, fig. 6). Under this, yellow ferruginous sands (*y*, fig. 6), with hydrate of iron and green sands, 30 feet thick, and without shells, succeed. I had no means of determining their age, whether they are contemporaneous with the beds of Mont Noir near Cassel, before described as containing Middle Eocene fossils, or whether they are part of the Limburg series, as I was assured by several Belgian geologists.

At a somewhat lower level, sands, containing unquestionable Eocene fossils, are seen in the fields at the points marked A. and B. in Map, fig. 3, Pl. XVII., but their contact with the incumbent beds, *y*, fig. 6, is not exposed. Scattered over these fields, which are often called indifferently "Jette" and "Laeken" by collectors of fossils, and also in a sand-pit from which shelly matter had been extracted for agricultural purposes, I found *Cytherea suberycinoides*, *Pecten corneus*,

Scalaria spirata, and *Nummulites variolarius*. The fossils obtained from the same beds by Captain Le Hon amount to the number of 76, and are enumerated in the column "Upper Brussels," Table XIII. p. 351. The following twenty species are among the more common, and the numbers appended, as furnished by Captain Le Hon, express their relative abundance.

Operculina Orbignyi	3	Pectunculus pulvinatus	3
Dactylopora cylindracea?	2	Stalagmium Nystii	4
Corbula rugosa?	3	Pecten imbricatus?	3
—— pisum	3	—— corneus	4
Crassatella trigonata	3	Dentalium substriatum	4
Lucina Galeottiana	1	Vermetus (Solarium) Nystii	4
Venus nitidula?	4	Turritella granulosa	3
Astarte Nystiana	2	Bulla lignaria	1
Cardium semigranulatum	2	Natica glaucinoides	1
Cardita elegans	2	Scalaria spirata	1

From these data Professor E. Forbes infers that the deposit took place either in the lowest part of the perilittoral zone or the upper division of the median zone, perhaps in 20 fathoms water.

The strata of greenish and yellowish sands from which these shells were derived are from 10 to 15 feet thick, where I saw them exposed. At other points near Dileghem, nodular sandstone occurs, containing casts of shells, some of which were collected by M. Déby many years ago in pits no longer open. The specimens which he presented to me contained *Nummulites variolarius*, together with casts of *Lucina globosa* and *Pectunculus pulvinatus*.

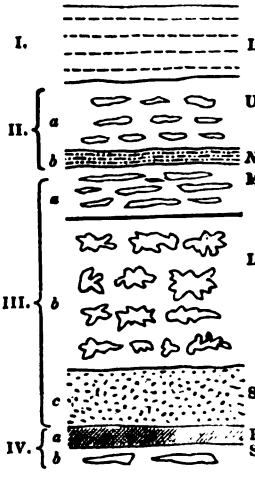
What I had seen at Cassel before my arrival at Brussels, and an examination of the section between Lille and Mons-en-Pevelle, which I shall mention in the sequel, had led me to conclude that the strata intervening between the Limburg series and the "London Clay proper" might be conveniently divided into three groups, distinguished among other characters by three different species of *Nummulites*,—*N. variolarius*, *N. lævigatus*, and *N. planulatus*. When I adopted this classification, I was not aware, or had forgotten, that the superposition of these three species in the order here assigned had been already recognized in the North of France, in 1842, by M. d'Archiac in his paper on the Department of the Aisne (Mém. de la Soc. Géol. de France, tom. v.). After my return from Belgium, when visiting Cuisse-Lamotte near Compiegne in France, I saw the shelly sands called "*sables inférieurs*" with *Nummulites planulatus*, surmounted by a nummulitic limestone, full of *N. lævigatus* and *N. scaber*, which is used as a building-stone at Mont Ganelon near Compiegne and other neighbouring places. Again, at Auvers, near Pontoise, north of Paris, I saw the lower *calcaire grossier* (or *glauconie grossière*), containing *Nummulites lævigatus*, and overlaid by sands (*sables moyens* or *grès de Beauchamp*) abounding in *N. variolarius**.

* Since my return from Brussels, M. d'Archiac has shown me, in a collection of fossils from Jette, a Nummulite which he could not distinguish from *N. planulatus*, mixed with *N. variolarius*. If the former species should be found to have endured down to the period of the "Laeken beds," its occurrence in them still appears to be an exception to the rule.

I must here take the opportunity of making a few remarks on the distribution of the three species of Nummulites, which are noticed in the text, in the English

After examining with Captain Le Hon the principal points where he had collected tertiary fossils in the neighbourhood of Brussels, I

TABLE XII. and Fig. 7.—*Subdivisions of the Middle Eocene Strata near Brussels.*



			Thickness. ft.	ft.	
I.		Laeken beds	10 to 25		E 1. Table I. p. 279.
II.	*a*	Upper Brussels sands, with occasional calcareous concretions	20		
	b	*Nummulites lævigatus* bed	2		
III.	*a*	Middle Brussels sands, fossiliferous, with calcareous concretions	10		E 2. Table I.
	b	Lower Brussels sands, with sandstone concretions, non-calcareous, or grotto-stones (*grès lustré*)	30 to 40		
	c	Siliceous sand, without fossils	40?		
IV.	*a*	Rock with *Num. planulatus*	2		E 2. Table I.
	b	Sand with sandstone and casts of shells	Unknown.		

found it easy, with the aid of his museum, to subdivide the strata in

Eocene beds,—a subject that has not as yet been satisfactorily treated, but towards the elucidation of which I have to offer the following facts:—

With Mr. Prestwich's kind assistance Mr. T. Rupert Jones has been enabled to examine the typical specimens of the Nummulites referred to in the list and description of the strata of the Alum Bay and White Cliff Bay Sections, published in 1846 (Quart. Journ. Geol. Soc. vol. ii. p. 252 *et seq.* and Pl. IX.); and this has led to the correction of some of the specific names there assigned to the Nummulites in question. By this examination Mr. Jones has found that in bed No. 11 of the White Cliff Bay Section (*i. e.* in the equivalent of part of the Bracklesham series), *Nummulites variolarius* (miscalled *N. elegans*, *loc. cit.* p. 254) occurs with *N. lævigatus* and *N. scaber*,—species which occur in two beds in contact with each other at Cassel, as above stated (see p. 329). In beds 12 to 14, still higher in the series, *N. lævigatus* and *N. scaber* alone occur (as is also the case at Bracklesham); and yet higher, in bed No. 16 (probably a member of the Barton group), *N. variolarius* (misnamed *N. elegans*, *loc. cit.*) occurs by itself, as in the uppermost division of the Nummulitic Eocene of France and Belgium. In the Barton Clay also (of Barton Cliff) *N. variolarius* is known to occur in great plenty and by itself, as well as at Stubbington.

There is also an important correction to be made in the list of fossils accompanying the description of the Alum Bay strata, *loc. cit.* p. 257, where two Nummulites are given as occurring in bed No. 29 (generally acknowledged to be the equivalent of the Barton beds). The specimens in Mr. Prestwich's collection, on re-examination, prove not to be, as there stated, *N. lævigatus* and *N. elegans*, but one form only, and that hitherto undescribed. This little Nummulite possesses characters distinct from those of *N. variolarius*, and somewhat approaches *N. planulatus*. In this circumstance we are reminded of the similarly anomalous position of the *Nummulites planulatus*, var.? in the highest part of the Belgian Nummulitic Eocene, at Jette, as above noticed.

I have elsewhere referred (p. 350, note) to the existence of *N. planulatus* (*N. elegans*, 'Min. Conch.') at Emsworth, near Chichester. I may add that the rock-specimen in which it occurs is a siliceous grit, containing the Nummulite in great numbers, together with casts of small gasteropods and bivalves.

the same manner as at Cassel and Lille. There are, however, such rapid changes in the mineral character of the sands of the Brussels district, even at short distances, that it would be endless to attempt to describe them all. The groups enumerated in Table XII. must simply be understood as expressing some of the more marked lithological and palæontological divisions.

The Laeken beds, Table XII. I., and E. 1. of Table I., already alluded to as occurring to the north of Brussels, are again found about two miles to the south of the city, on the road-side between St. Gilles and Forêt, on ascending to the higher grounds at the point C, Map, fig. 3, Pl. XVII. They there consist of greenish sands, about 10 feet thick, which are considered by Captain Le Hon as the lowest part of the Laeken beds. In these I found

Nummulites variolarius, *Lamk.*
Turbinolia Nystiana, *Haime.*
Lunulites radiatus? *Lamk.*
Corbula pisum, *Sow.*
Cypricardia pectinifera, *Morris.*
Nucula margaritacea? *Martini.*
Pecten plebeius?, *Lamk.*
Anomia lævigata, *Sow.*
Ostrea flabellula, *Lamk.*
Dentalium Deshayesianum, *Galeotti.*
Turritella granulosa, *Desh.*
Echinocyamus propinquus, *Galeotti*, sp.

The position of these beds to the south of Brussels may be seen at E. 1, fig. 8, where they are covered by ferruginous sands without fossils (*y*), probably of the same age as those at *y* in Section fig. 6.

[2.] *Brussels beds, or Middle Nummulitic. Upper Brussels Sands.*

Next below the Laeken beds come those strata which are commonly called "Bruxellian" by the Belgian geologists, and which correspond to E. 2 of Table I. p. 279, and to II. *a* & *b*, Table XII. They consist of the Upper Brussels Sands, with a bed containing *Nummulites lævigatus* at the base. The chief points where fossils have been obtained in them are the following:—

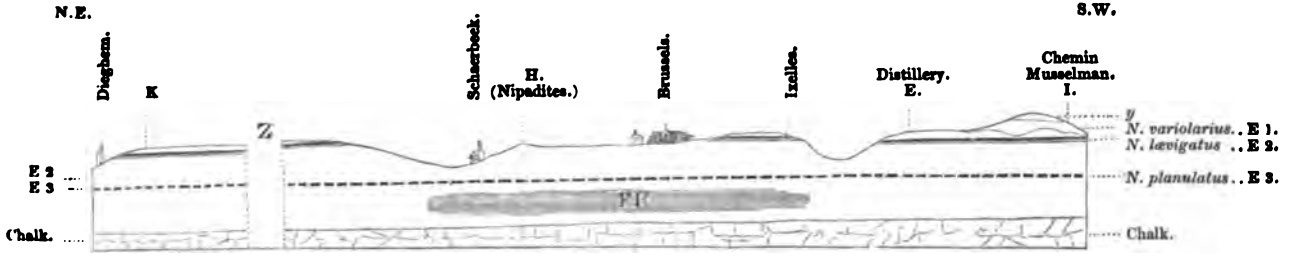
(1.) *St. Gilles. Chaussée Louise* (D. Map, fig. 3, Pl. XVII.).

In the southern suburb of Brussels, on the side of the high-road called Chaussée Louise, greenish sands are seen, which are from 15 to 20 feet thick at the point D of the Map, fig. 3, Pl. XVII., and exhibit two or three layers of large flattened concretions of sandstone, which effervesce with acids. The following fossils in Captain Le Hon's collection were obtained from this spot:—

*Nummulites lævigatus, *Lamk.* } in a bed at the base of the section.
* —— scaber, *Lamk.* }
Membranopora.
*Lichenopora.
*Orbitolites complanatus, *Lamk.*
*Lunulites radiatus?, *Lamk.*
*Idmonea triquetra, *Lamx.*
*Gastrochæna.
*Pecten plebeius, *Lamk.*
—— corneus, *Sow.*
*Anomia lævigata, *Sow.*
*Ostrea flabellula, *Lamk.*, and O. virgata, *Goldf.*
*Dentalium Deshayesianum, *Gal.*
*Spatangus Omalii, *Gal.*
*Echinolampas affinis?, *Goldf.*
*Lenita patelloides, *Galeotti*, sp.
Nucleolites approximatus, *Galeotti.*
*Cidarites?, sp. nov.
*Echinocyamus propinquus, *Gal.*
*Scutellina rotunda, *Gal.*
Cancer Burtini?, claws of.
——, smaller species.
Lamna, teeth of

The species marked with * occur also at the Distillery; *vide infra.*

Fig. 8.—*Section passing through Brussels along the Line of Section* I, K, *on the* Map, fig. 3, Pl. XIII.



y. Unfossiliferous sands.
E 1. Lacken beds, or Upper Nummulitic.
E 2. Brussels beds, or Middle Nummulitic.
E 3. Lower Nummulitic beds.

Z. Break of several miles on the higher part of the platform south of Dieghem.
K, H, E, I. Points laid down in the Map, fig. 3, Pl. XVII.

The double line represents the *Nummulites lævigatus* bed.
The broken line represents the supposed place of the rock with *N. planulatus*, the position of which is ascertained at I. and H., or below the Scheerbeek quarry, by boring.

F ? ?. London Clay ?, reached by boring at Brussels.

The chalk was found at the depth of about 250 feet below the river, in the outskirts of the city.

Note. The strata undulate more than is here expressed, but on the whole they appear to dip slightly to the north.

(2.) *St. Gilles. Fabrique d'eau forte* (E. Map, fig. 3, Pl. XVII., and Section, fig. 8).

Another locality where the upper Brussels sands immediately below the Laeken beds are seen with the *Nummulites lævigatus* bed at their base, is in the suburb called St. Gilles, at the Distillery "Fabrique d'eau forte," on the high-road to Waterloo. The fossils which I collected there, or which are in Captain Le Hon's cabinet, are first the seventeen species to which an asterisk is prefixed in the preceding list, and in addition, the two following:—

Scalaria, allied to *S. spirata*; perhaps a variety.
Cœlorhynchus rectus, *Agas.* (found by M. Nyst).

The bed (*Nummulites lævigatus* bed) on which the sands above-described repose at the "Fabrique d'eau forte," is full of a prodigious quantity of fish-teeth, much rolled, of the genera *Lamna*, *Otodus*, *Myliobates*, *Cœlorhynchus*, and *Edaphodon*, mixed with fragments of *Asterias*.

Among the fossil teeth in Captain Le Hon's collection, found at this spot, and in the same Nummulite-bed at several places in the neighbourhood, I have recognized the following species:—

Fossil Fish in the gravelly bed with Nummulites lævigatus.

Lamna elegans, *Ag.*
Otodus obliquus ?, *Ag.*
Pristis, resembling that figured in Dixon's 'Foss. Suss.,' pl. 10. fig. 6.
Myliobates Dixoni, *Ag.* Dixon, pl. 10. fig. 2, and pl. 12. fig. 3.
—— striatus, *Ag.* Dixon, pl. 12. fig. 2.
Edaphodon Bucklandi. Dixon, pl. 10. fig. 21.

Saurian from the Num. lævigatus bed.

Gavialis Dixoni ?, *Owen*, Dixon, pl. 12. fig. 24.

A single tooth, much resembling the figure above cited (a Saurian from the Eocene deposits of Bracklesham), was found by Captain Le Hon with the fish-teeth.

From the data supplied by Captain Le Hon respecting the relative abundance of the Echinoderms and Molluscs in the *Nummulites lævigatus* bed at this point, and in some other adjacent localities, Prof. Forbes infers the depth of the water to have been about 15 fathoms.

I observed at the same spot at St. Gilles a remarkable proof of the denudation of the underlying Eocene beds previously to the formation of the *Nummulites lævigatus* bed. A cast of *Rostellaria ampla* in a siliceous sandstone accompanies the Nummulites, and on some of the whorls (the shell itself having wholly disappeared) are seen two species of Bryozoa (*Escharina* and another) adherent. The small cells as well as their bases remain, and it is clear that they originally covered the surface of the cast after the shell itself had been dissolved.

(3.) *St. Gilles. Fort Monterey* (F. Map, fig. 3, Pl. XVII.).

In the parish of St. Gilles, near Fort Monterey, in a pit not far

from the toll-gate (where the road goes off to Forêt), the remains of a *Nautilus* (probably *N. Burtini*), with a cast of a large *Crassatella*, a *Tellina*, and several of the shells mentioned in the former lists, occur, with *Nummulites lævigatus*.

(4.) *Ixelles. South-east suburb of Brussels* (Map, fig. 3, Pl. XVII., and Section, fig. 8).

In a quarry at Ixelles, the same Nummulite-bed has afforded the following species:—

Nummulites lævigatus, *Lamk.*
—— scaber, *Lamk.*
Cardita planicostata, *Lamk.*
Pecten plebeius, *Lamk.*
——, another species.
Ostrea carinata, *Desh.*
—— flabellula, *Lamk.*
Terebratula Kickxii, *Gal.*
Rostellaria ampla, *Brander.*
Bulla.
Nautilus, mandibles of.
Asterias (Goniaster poritoides?, *Desm.*).
Lamna.
Otodus.
Galeocerdo.
Myliobates.
Pristis Lathami, *Gal.*
Cœlorhynchus rectus?, *Ag.*

(5.) *Etterbeek, two miles east of Brussels* (Map, fig. 3, Pl. XVII.).

In a road-side quarry which I visited with Captain Le Hon, between Etterbeek and Woluwe-St.-Pierre, at the point G, Map, fig. 3, Pl. XVII., we observed the *Nummulites lævigatus* not forming a distinct bed, as usual, but disseminated through sands which contained the following fossils:—

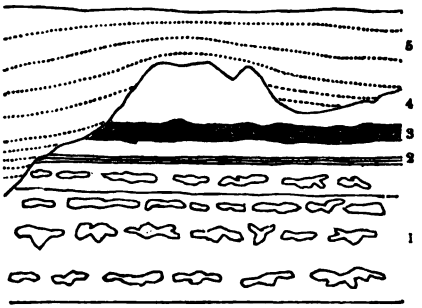
Nummulites lævigatus, *Lamk.*
—— scaber, *Lamk.*
Orbitolites complanatus, *Lamk.*
Flustra contexta?, *Mich.*
Bryozoon, small and branched.
Serpula, allied to *S. triquetra.*
——, two other species.
Gastrochæna.
Pecten plebeius?, *Lamk.*
Spondylus.
Anomia lævigata, *Sow.*
Ostrea inflata, *Desh.*
—— gryphina, *Desh.*
Ostrea carinata, *Desh.*
—— virgata, *Goldf.*
—— flabellula, *Lamk.*
—— cymbula, *Lamk.*
——, sp. nov.
Terebratula Kickxii, *Gal.*
Crania Hoëninghausii, *Michelotti.*
Dentalium (Ditrupa) Deshayesianum, *Gal.*
Asterias (Goniaster poritoides?, *Desm.*).
Echinolampas affinis?, *Goldf.*, sp.
Spatangus Omalii, *Gal.*
Cœlorhynchus rectus, *Ag.*

(6.) *Dieghem, seven miles north-east of Brussels.*

It will be seen by reference to Section, fig. 8, p. 336, that the city of Brussels stands, for the most part, on the beds which are next below that containing *Nummulites lævigatus*; but in following the line of section (I, K, Map, fig. 3, Pl. XVII. and fig. 8) to Dieghem, seven miles north-east of Brussels, this bed is exposed to view in the quarries there with the usual fossils, although its thickness does not exceed 2 feet. It is for the most part covered immediately with white calcareous sand, belonging to the beds E, which, like the Nummulite-bed, have been much denuded. Over both are newer yellow sands and pebbly beds, the age of which I could not determine for want of organic remains. The manner in which the nummulitic bed, and the

Eocene strata immediately overlying and underlying it, have suffered denudation (sometimes to the depth of 20 and 25 feet), is shown in the annexed diagram.

Fig. 9.—*Section at Dieghem, seven miles N.E. of Brussels.*



1. Siliceous sand with layers of grotto-stones, E 2, Table I., or III. *b*, Table XII.
2. Siliceous schist or tripoli.
3. *Nummulites lævigatus* bed, with *Crania*.
4. White sand, II. *a*, Table XII.
5. Newer sands, 25 feet thick.

All the peculiar characters of the Nummulite-bed, already described as belonging to it round Brussels, are repeated in this quarry. It may be termed a gravel-bed, with quartz-sand, pebbles, and rolled fragments (generally small, but occasionally of a large size) of a rock formed of aggregated remains of *Nummulites lævigatus*, which after having been consolidated must have been broken up. On these fragments partially rounded, and often several inches in diameter, are numerous adhering shells, of the genera *Ostrea*, *Spondylus*, and *Crania*, also *Serpulæ* and several *Bryozoa* attached to pebbles or to the valves of molluscs. *Terebratula Kickxii* likewise occurs in this bed, but no univalve shells. The presence of the *Crania*, so rare in tertiary strata, is interesting. The same shell had been observed by Captain Le Hon at Etterbeek, as already mentioned, before I visited Dieghem. Mr. Davidson considers this species inseparable from *Crania Hoëninghausii* of Michelotti*. The shells are of the same size, and, although his figures are small, they offer the same characters as the Belgian shell, which, Mr. Davidson remarks, is less conical than D'Orbigny's *Crania cenomanensis*, which it most resembles. Whether the tertiary beds at Turin, from which Michelotti obtained his specimen, agree in age with those of Brussels, I cannot decide.

A magnified representation of this *Crania* is given in Pl. XVIII. fig. 8, and the following description has been drawn up by my friend Mr. Davidson.

CRANIA HOËNINGHAUSII, Michelotti, 1847. [Pl. XVIII. fig. 8.]

Shell irregular, inæquivalve, transversely oval, slightly conical,

* Hill of Turin. Fossiles des Terrains Miocènes de l'Italie Septent. 1847, p. 79, pl. 2. fig. 23, 24.

patelliform, depressed; vertex almost central; surface exteriorly unequal and rugose. Interior of upper valve (the only one known) concave, margin narrow, granulated. Four muscular impressions; the posterior ones are more or less circular, lying close to the inner edge of the granulated margin, and separated from each other by a flat space not equal in size to one of the muscular impressions; the anterior pair are irregularly oval, diverging from near the centre towards the posterior lateral margin: a slight prominence existing before the central pair. Vascular impressions not well defined. Structure punctuated. Length 4 lines. Breadth 4½ lines. Depth 1 line.

Locality. Eocene beds of Dieghem, near Brussels, and in the beds of the Hill of Turin.

Fossil Echinoderms.

In the foregoing lists of fossils from the Upper Brussels sands, the names of six species of Echinoderms have been enumerated; and I have mentioned, besides, the *Echinolampas Galeottianus*, as found a few feet above the Nummulite-bed at Cassel. Excepting *E. affinis*?, figures of all these are given in Pl. VIII.; and Professor E. Forbes has had the kindness to draw up the following descriptions.

Note on the Eocene Echinoderms *procured by* Sir Charles Lyell *in* Belgium. By Professor E. Forbes, F.R.S., F.G.S.

In M. Galeotti's Memoir on the Geology of Brabant, he enumerates eight species of fossil sea-urchins, and figures seven of them as new, but without detailed descriptions. The figures are very slight, and, in the present state of the subject, insufficient. Additional representations of these interesting fossils are, therefore, much to be desired, and some additional information respecting their characters cannot fail to prove useful.

Sir Charles Lyell has submitted to my examination seven tertiary Sea-urchins from Belgium (exclusive of *Echinolampas affinis*?). All but one among these appear to be identical with Galeotti's species. They are represented in Pl. VIII. of this volume.

Echinolampas Galeottianus, n. sp. Pl. VIII. fig. 1, *a*, *b*, *c*.

These figures represent an *Echinolampas* not included in Galeotti's list. It was found in abundance by Sir Charles Lyell in the Hill of Cassel, near Dunkirk, and named for him by some of the Belgian naturalists, *Clypeaster* (i. e. *Echinolampas*) *affinis* of Goldfuss. It differs in some material points from the figure of that species in the 'Petrefacta Germaniæ,' and, as several very perfect specimens have been submitted to my examination, all of which exhibit the same features, I feel warranted in regarding them as examples of a distinct form of this genus, and to which, as the species appears to be undescribed, I would assign the name of *Echinolampas Galeottianus*.

A large example measures 2½ inches in length by 2$\frac{3}{10}$ths in breadth. Its greatest thickness (somewhat in front of the apex) is $\frac{10}{12}$ths of an

inch. Above it is regularly convex, with the apex eccentric and anteal. In front of the apex, the anteal ambulacral region is declining and depressed, but forms a tumid curve before reaching the margin. Behind it the back rises gradually and describes a regularly swelling but rapidly declining curve, until it reaches the posterior margin. The ambulacral petals of the back are lanceolate; that of the anteal ambulacrum is nearly symmetrical; the lateral ones are slightly inequilateral; the postero-laterals are slightly longer than the antero-laterals. They diverge at a considerable angle, and their extremities do not approach the margin so nearly as those of the antero-laterals. There are about fifty-two pairs of pores in each row in the anteal ambulacrum, and seventy or more in the lateral. They are placed in very slight depressions, and the pores are connected by grooves, separated by narrow granulated ridges. The whole surface of the test above and below is studded with nearly equal minute tubercles, lodged in areolæ. The mouth is very eccentric, and the buccal ambulacra are separated by swellings of the test. The vent is infra-marginal and transversely ovate.

It differs from *Echinolampas affinis* in having a compressed (not tumid) margin, in regularly declining with a gentle curve in its posterior region, and in having its mouth much more eccentric.

ECHINOLAMPAS AFFINIS?, Goldf. sp. [Not figured.]

A specimen of *Echinolampas*, from the neighbourhood of Brussels, was presented to Sir C. Lyell by Captain Le Hon, with the name of *Galerites ovalis*; this may, perhaps, prove to be the *Clypeaster affinis* of Goldfuss.

ECHINOLAMPAS DEKINI, Galeotti, sp. Pl. VIII. fig. 2, *a*, *b*, *c*.

This is the *Galerites Dekini* of Galeotti, pl. 4. *b*, Suppl., fig. 10. It is a good species, with a tumid test, much swollen throughout the posteal region. Its apex is very eccentric. The petals are lanceolate and not strongly marked; the two postero-laterals are longest. The tuberculation of the surface is equal and minute. The mouth and vent are both transverse; the former eccentric and lodged in a depressed area, with tumidities surrounding it. The figure represents this specimen of the natural size.

NUCLEOLITES APPROXIMATUS, Galeotti. Pl. VIII. fig. 3, *a*, *b*, *c*.

The specimen of this rare fossil is unfortunately in bad condition. It appears to be a true *Nucleolites* and is exceedingly interesting, since it is the only tertiary example of the genus with which I am acquainted having an anal groove; it thereby in some respects helps to fill up the gap between the cretaceous *Nucleolites* of this division and the unique existing *Nucleolites recens* of the seas of New Holland.

ECHINOCYAMUS PROPINQUUS, Galeotti. Pl. VIII. fig. 4, *a*, *b*, *c*.

This appears to be a good species, but in this genus it is very difficult to find good characters. The position of the vent, away from the margin, reminds us of the existing *Echinocyamus pusillus*.

SCUTELLINA ROTUNDA, Galeotti, sp. Pl. VIII. fig. 5, *a*, *b*, *c*.

This is *Nucleolites rotundus* of Galeotti. It is a species of *Scutellina* and approaches very nearly to *S. placentula* of the Parisian tertiaries.

LENITA PATELLOIDES, Galeotti, sp. Pl. VIII. fig. 6, *a*, *b*, *c*.

This is *Nucleolites patelloides* of Galeotti. Sir Charles Lyell received it from Capt. Le Hon as the *Lenita patellaris* of Goldfuss, but it differs from that species in having its vent placed very near to the margin, and in being more convex. In the group of sea-urchins to which it belongs, the position of the vent is very constant, and affords a certain indication of specific character. I regard it as a truly good species: it will stand as *Lenita patelloides*.

SPATANGUS OMALII, Galeotti. Pl. VIII. fig. 7, *a*, *b*.

The *Spatangus Omalii* of Galeotti is allied to the *Spatangus Hoffmanni* of Goldfuss. Galeotti represents a very bad and worn specimen, and omits the few large and scattered areolæ with their included primary tubercles that ornament the antero-lateral and lateral inter-ambulacral areas. The mouth is placed very far from the margin, and the anal extremity is abruptly truncated. It appears to be identical with fragments of a *Spatangus* found in the Barton beds by Mr. Frederic Edwards. The following revised description of this species may be serviceable:—

Test cordate, depressed; anterior furrow strongly marked and subcarinated at its sides. Ventral extremity abruptly truncated, with the anus placed moderately high up. Back slightly carinate. Dorsal ambulacra ovate; pores connected by wide sulcations. Antero-laterals widely diverging; postero-laterals meeting at an acute angle. Number of pairs of pores in a row, about 12 in the former and 14 in the latter. Areolæ very deeply impressed. Primaries confined to anterior and middle portions of test. A group of primary tubercles on each side of caudal projection. Mouth rather far from anteal margin. Ventral surface very flat.

[3.] *Fossiliferous Brussels Sands with calcareous concretions.*
(III. *a*, Table XII. p. 334. Part of E 2, Table I. p. 279.)

Next to the *Nummulites lævigatus* bed we find, in the descending order, white sands which are in some places so calcareous as to have been burnt for lime in the suburbs of Brussels and at Dieghem, where I saw several kilns. These beds usually contain nodules of sandstone in layers, with casts of shells; sometimes the shell itself is present, either silicified, or, if it retain its calcareous matter, so decomposed as to fall to pieces when touched.

(1.) *Rouge Cloître, near Auderghem.*

At Rouge Cloître, near Auderghem, five miles south-east of Brussels, these calcareous beds, with some shells (silicified or in casts), are found about 4 feet thick, and have afforded the following shells which are in Capt. Le Hon's cabinet:—

Fossils from Rouge Cloître, near Auderghem, five miles S.E. of Brussels.

Turbinolia crispa, *Lamk.*
Polyparia.
Corbula umbonella, *Desh.*
*—— gallica, *Lamk.*
Mactra semisulcata, *Lamk.*
Tellina tenuistriata, *Desh.*
Lucina sulcata, *Lamk.*; abundant.
*—— divaricata, *Lamk.*; abundant.
—— gibbosa.
*Cytherea suberycinoides, *Desh.*; very abundant.
—— semisulcata, *Lamk.*
*—— lævigata, *Lamk.*
*Cardium porulosum, *Brander.*
——, another species.
Cardita.
Venericardia planicostata, *Desh.*
—— decussata, *Münst.*
Pectunculus (small).
Arca barbatula, *Lamk.*
Pecten corneus? *Sow.*
Anomia lævigata, *Sow.*
Ostrea virgata, *Goldf.*, or O. flabellula, *Lamk.*
Calyptræa trochiformis, *Lamk.*
Solarium grande? *Nyst.*
—— patulum? *Lamk.*
—— trochiforme, *Desh.*
Trochus conchyliformis (non *agglutinans*).
Turritella terebellata, *Lamk.*
Tornatella.
Natica spirata, *Bronn.*
—— patula, *Desh.*
—— sigaretina? ?, *Lamk.*
—— epiglottina, *Lamk.*
—— labellata, *Lamk.*
Sigaretus canaliculatus, *Sow.*
Fusus ficulneus, *Lamk.*
—— errans, *Sow.*
—— elongatus, *Nyst.*
—— bulbiformis, *Lamk.*
——, with long beak.
Pleurotoma?
Cerithium?
Pyrula.
Rostellaria macroptera, *Lamk.*
—— fissurella, *Lamk.*
Cassidaria carinata, *Lamk.*
—— nodosa? *Nyst.*
——, sp. nov.
Buccinum stromboides, *Herm.*
Conus deperditus, *Brug.*
—— turritus, *Lamk.*
Voluta cithara? *Lamk.*
Oliva.
Sepia Cuvieri, *d'Orb.*
Beloptera?
Lamna, teeth.
Vertebræ of Shark and other Fish.

(2.) *St. Joose-ten-Noode.*

At this locality, in the eastern suburbs of Brussels, are some pits near the high-road to Louvain, in which many fossils have been obtained, agreeing for the most part with those of Auderghem. Those five species, for example, to which an asterisk is prefixed in the preceding list, occur at St. Joose-ten-Noode, and with them

Tellina rostralis.
—— planata, and another species.
Pinna margaritacea.
Murex tricarinatus.
Rostellaria(casts), probably R. fissurella.
Voluta (V. lyra or spinosa?).
Teeth of Lamna.
Myliobates.

One or two of these species, as *Tellina rostralis*, are shells usually confined to the Laeken beds. At Groenendal, three miles south of Brussels, many of the Auderghem shells are found in a ferruginous matrix.

(3.) *Schaerbeek.* (H, Map, fig. 3, Pl. XVII., and Section, fig. 8.)

The stone quarries at Schaerbeek, in the northern suburbs of Brussels, have long been celebrated for the fossil Fruits, called Cocoanuts, and for fossil Tortoises, found there in concretionary nodules. It

* The species to which an asterisk is prefixed occur also at St. Joose-ten-Noode.

will be seen by the section, fig. 8. p. 336, that the beds in this quarry are below the level of the *Nummulites lævigatus* bed.

In the principal quarry, the Middle Brussels beds (III. *a*, Table XII. p. 334), seen in the highest part of the section, consist of sands 10 feet thick, with several layers of stone. Some of these layers are almost continuous and afford flat paving-stones. These beds contain both argillaceous and calcareous matter, and in some of them occur the oval-shaped fossil Fruits (*Cocos Burtini*, Brongniart), referred to *Nipadites* by Mr. Bowerbank. Some of these are silicified, and the wood both of Palms and dicotyledonous trees are found in the same strata perfectly silicified.

At the time of my visit the workmen showed me the trunk of an exogenous tree with forty rings of annual growth, which they had just extracted. It had lain in a horizontal position and was bored by *Teredinæ*. Capt. Le Hon also possesses the stool of a Palm-tree, perfectly silicified, consisting of the base of the trunk, which seems to have been broken off short at about the level of the soil, and to which numerous air-roots or rootlets remain attached, such as palms very commonly throw out above the surface of the soil, the whole exhibiting structure beautifully preserved. Captain Nelson, to whom I showed this specimen (Capt. Le Hon having kindly allowed me to bring it over to England), recognized it as bearing a striking resemblance to what are called "palm-cups" in the West Indies. When an old cocoa-nut tree decays and breaks off near the ground, the central woody portion, which in endogenous trees consists of a spongy tissue, contracts more than the external or more solid wood, while the roots scarcely shrink at all. This produces a convexity in the middle, and may explain a similar cavity in the Schaerbeek fossil. The concave surface of the broken and shrunk wood exhibits a great number of small deep pits, caused by bundles of fibres having been pulled out when the fracture took place.

Nipadites, or the fossil Fruits of Palms.

The most interesting remains of fossil plants in the Schaerbeek quarries are those oval fruits already mentioned, which Burtin described in his 'Oryctographie de Bruxelles,' in 1784, and which he regarded as cocoa-nuts. They have been named by Mr. Bowerbank *Nipadites*, as being nearly allied to the *Nipa fruticans*, a palm which abounds in the delta of the Ganges and other parts of Bengal, and is the only living species of the genus known. M. Adolphe Brongniart has adopted the same generic name, and has observed that some of the fossil fruits of Brussels are sufficiently perfect to show that they want the ligneous endocarp marked by three pores, which is so characteristic of the cocoa-nut.

Mr. Bowerbank* enumerates thirteen species of *Nipadites* from the London Clay of the Isle of Sheppey, and considers that the Schaerbeek fossils, which Capt. De Hon kindly lent me to figure, belong to no less than four of his British species; viz.—

* 'Fossil Fruits and Seeds of the London Clay,' 1840.

1. Nipadites turgidus, *Bowerbank*, '*Fossil Fruits*,' pl. 5. [Pl. XIX. fig. 1, & Pl. XX. figs. 7, 8.]
2. N. giganteus, *Bowerbank*, pl. 6. fig. 1. [Pl. XIX. fig. 2.]

} *Nipadites Burtini*, (according to Dr. Hooker).

3. N. lanceolatus, *Bowerbank*, pl. 3. fig. 7 & 8. [Pl. XIX. fig. 3, 4.]
4. N. Parkinsonis, *Bowerbank*, pl. 4. [Pl. XIX. figs. 5, 6.]

The first two of these are considered by Dr. Hooker as probably belonging to the same species, which should be called *Nipadites Burtini*, Brongn. sp. Many of Mr. Bowerbank's species, as he is now aware, may be founded on differences which appertain to individual varieties, or are still more frequently the result of different stages of growth, and of pressure in fruits aggregated into bunches. They were selected by him as the most striking and constant forms out of many hundreds of individuals from Sheppey.

Nipadites Burtini, Brongniart, sp.
[Pl. XIX. figs. 1, 2, & Pl. XX. figs. 7, 8.]

Length of the largest Schaerbeek specimen, 7 inches $\frac{5}{10}$ths; breadth 4 inches.

Fig. 1 represents a ripe specimen called *N. turgidus* by Mr. Bowerbank. Burtin's figure, pl. 30. fig. A, is good, but Capt. Le Hon's specimen (here figured) displays more fully the texture and form both of the pericarp and its contained seed.

Pl. XX. fig. 7. Side view of another specimen, showing the marks of boring Molluscs, probably *Teredinæ*.

Pl. XX. fig. 8. Base of the same specimen, broken off at *a*, fig. 7, showing hollows made by *Teredinæ* and filled by sandstone, the cavity of the pericarp being similarly filled (*a*, *b*).

Pl. XIX. fig. 2. *N. giganteus*, Bow., is according to Dr. Hooker an immature or abortive fruit of the same species, showing the angularity of the pericarp, equally characteristic of this and of the ripe specimen. From the sharpness of the prominent ridge and the gibbosity of its general shape, the fossil singularly resembles the living *Nipa fruticans*, with which it also agrees in the coarsely fibrous texture of the pericarp.

Dr. Hooker has shown me seeds taken from the same head of *Nipa fruticans*, from the Sunderbunds of the Ganges, differing much more widely from one another in form and outline than *N. turgidus* and *N. giganteus*. One of the recent specimens is not so much as one-fifth the size of another in the same bunch.

Some of Mr. Bowerbank's specimens from Sheppey are not inferior in size to those of Brussels. If the nuts were equally numerous in the same head, a cluster of them must have very far exceeded in magnitude the head of the living *Nipa*. The absence of nuts in many of the full-grown pericarps at Schaerbeek is quite natural, as I learn from Dr. Hooker that the top seed-vessels are most commonly abortive in the living *Nipa*, as are frequently some of those in the rest of the bunch.

Several of the Schaerbeek fruits are drilled by *Teredinæ*, and have the pericarp silicified.

NIPADITES LANCEOLATUS, Bowerbank, pl. 3. fig. 7, 8, and N. CLAVATUS?, Bowerbank, pl. 3. figs. 4, 5, 6.

[Pl. XIX. figs. 3, 4.]

Fig. 3 represents a fruit split open, exposing the cast of the pericarp (*a*) and a cast of the nut, or of its cavity (*b*), bearing an impression of the endocarp.

Fig. 4 is a lateral or edge-view of this same body or nucleus, removed from the pericarp, and shows the point of attachment at its base. There are no remains of vegetable tissue in any part of the specimen.

NIPADITES PARKINSONIS, Bowerbank, sp. (pl. 4).
Cocos Parkinsonis, Ad. Brongn., Prodrome, p. 121.

[Pl. XIX. figs. 5, 6.]

Length of Schaerbeek specimen 1 inch $\frac{4}{10}$ths, breadth 1 inch $\frac{1}{10}$th.

Fig. 5 *a*.—Cast of the outside of the pericarp.

Fig. 5 *b*.—Nucleus or cast of the endocarp or inner surface of the pericarp. In this, as in other specimens, the nucleus resembles the seed in form, but is without trace of tissue.

Fig. 6.—Another view of the nucleus, showing the opening where the sand entered at the base.

All the above figures are reduced to half the length of the fossils.

HONIUM BRUXELLIENSE.

[Pl. XX. fig. 1–6 *b*.]

I have given to this curious fossil from Schaerbeek, which I am inclined to consider a Sponge, the generic name of *Honium*, from its discoverer Captain Le Hon. Many conjectures have been formed by palæontologists as to its true nature, some having suggested that it may prove to be part of the spadix or catkin of some cycadeous plant, as, in their opinion, it was composed chiefly of cellular tissue. But Dr. Hooker tells me he has never seen in any plant such reticulated structure as is exhibited in part of the *Honium*, so that he is opposed to the opinion of its being of vegetable origin. It may perhaps be allied to a Sponge, as it contains many spines which agree in form with the *spicula* of Sponges: but we can scarcely be sure that such spines really belong to the fossil, because both specimens of the *Honium* figured in Pl. XX. contain many spines of an Echinoderm, which are certainly foreign to the body itself, and many of which may be seen scattered through the rock, although nowhere in such thick clusters as on one of the specimens of *Honium*. A small portion of the cast of the test of a *Spatangus*, however, is preserved in one of the stones containing *Nipadites*, from the same stratum at Schaerbeek, showing the co-existence of Echinoderms with the *Honium*.

The convergence of the lines of pits in the reticulation towards

the peduncle appears to Dr. Hooker to be unlike plant-structure. Some Sponges, on the other hand, offer a similar appearance.

Pl. XX. fig. 1. represents this fossil, of the natural size. It is a cast of a transversely obtuse-oval body, with a sinus on its upper or longer edge, and opposite to this a stem-like tapering projection or peduncle. This surface of the cast is convex, and the other surface, on the corresponding fragment of the nodule, which has not been preserved, was probably parallel to it, a slight cavity intervening; traces of a furrow at the margin of the cast (fig. 5 *a*) remain to indicate the thickness of the blunt edges of the *Honium*, which was probably less than $\frac{1}{10}$th of an inch. The stem or peduncle was continued into the body, as shown by a granular ridge upon the surface of the cast; in other words, a thin ridge runs from about the centre of the surface of the body down towards the peduncle. Imbedded in the surface of this specimen are seen clusters of *spicula*; and a small portion of it retains a reticulated surface, which is still better shown in the specimen fig. 2, where at one spot the reticulation passes over the spines.

Pl. XX. fig. 6^a and 6^b.—Magnified representations of the *spicula* from the above-described specimen, fig. 1; *a*, and *c*, *c*, *Spicula* of Sponge?, *b* and *d*, Spines of a *Spatangus*.

All of these are more or less coated with the same earthy matter which cements the sandstone in which they are imbedded. The grains of sand being enveloped with the same calcareo-siliceous cement, are thus often joined to the *spicula*, and when these grains happen to adhere to the end of a *spiculum* they give it the appearance of a spine with a bulbous base. The *spicula* vary in length from $\frac{1}{10}$ to $\frac{1}{13}$ inch.

Fig. 2. (Natural size.)—Another specimen of *Honium*. Only a few *spicula* are dispersed over it, and the surface is nearly covered by a fine network.

Fig. 3.—A portion from near the centre of the surface of fig. 2, magnified.

Fig. 4.—Another portion from the central part of the same specimen, showing the reticulated surface, *b*, converging towards, and passing under the granular ridge, *a*.

Fig. 5, *a*.—Magnified representation of part of the surface at the edge near the stem, on the right-hand side of fig. 2.

Fig. 5, *b*.—Portion of the surface in the sinus (fig. 2), where the network assumes the aspect of a wrinkled membrane, or of a membrane to which a cellular tissue has been attached, the rest of the tissue being destroyed.

Patches of a black, carbonaceous, pulverulent matter stain the hollows in both specimens.

It appears that the stony beds at Schaerbeek (III. *a*, Table XII. p. 334), which contain the above-mentioned *Honium* and *Nipadites*, with much fossil wood of palms and dicotyledonous trees, were formed in the sea, near the mouth of a river, as in the case of the clay at Sheppey; and the fruits prove that the same species of *Nipadites* which flourished at the period of the London Clay proper continued

to abound at an era more nearly corresponding with that of the Bracklesham beds. I have already mentioned that in the Hill of Cassel I found *Nipadites*, bored by *Teredinæ*, at a somewhat higher geological level, or in the beds containing *Nummulites variolarius* (see p. 328). Teeth of Sharks occasionally occur in the same beds with the Fruits at Schaerbeek, together with *Ostrea flabellula* and a *Pinna* (*P. margaritacea*?), showing that the water was salt; while the influence of a river is attested by the occasional presence of fresh-water Tortoises. One of these, obtained by Captain Le Hon, exhibits a perfect carapace, 1 foot long by 10 inches in breadth, and is probably the *Emys Cuvieri*, Galeotti, figured by Burtin. According to Professor Owen, to whom it has been submitted, it is a perfect cast of the inner surface of the carapace, with the hinder marginal plates dilated, but in no part showing the scutation; so that the species could not be determined, although it may be pronounced to be "a freshwater or estuary Emydian."

I learn from Captain Le Hon that the marine Fish, figured by Burtin in his 'Oryctography of Brussels,' plates 3 and 4 (*Zeus auratus*, Blainville, and *Pleuronectes maximus*, Blainville), occur at the same level as the *Nipadites*, *Honium*, and Emydian Tortoise above-described.

At Saventham, near Brussels, fossils similar to those at Schaerbeek are found in a like position.

[4.] *Lower Brussels Sands with "grotto-stones,"* &c. (III. *b*. Table XII. p. 334.)

The calcareous bands (III. *a*. Table XII.) last mentioned are about 10 feet thick. Below them, at Schaerbeek, other sands are found, 40 feet thick, with many layers (not less than twenty) of irregularly-shaped nodules of sandstone, called *pierres de grottes* or *grès lustré*, from the shining glossy lustre of the fractured surface. They consist of aggregations of siliceous sand with a siliceous cement, such as that which has petrified the fossil trees. The interior of a nodule is often a cherty mass. The shapes of these stones are extremely irregular, and sometimes quite grotesque. Sharks' teeth and shells, especially *Ostrea flabellula* and *O. virgata*, are seen half-entangled in the solid mass and half-projecting from the surface of the nodule, the loose sand having fallen away from the exterior. Besides the more regular beds of grotto-stones some scattered concretions occur, resembling the branches of trees in shape. From the abundance of these in certain districts the name of *grès fistuleux* has been given to this division, III. *b*.

Below these beds are the sands III. *c*, which consist of white siliceous sands without fossils; and below these a stratum of rock with *Nummulites planulatus* has been found by boring at Schaerbeek at the depth of 70 feet, to which I shall presently allude.

[5.] *Dieghem Schistose Tripoli*. (Table XII. III. *a*, and fig. 9, p. 339.)

In the Dieghem quarries already mentioned, which are above 60 feet in depth, immediately under the *Nummulites lævigatus* bed I found continuous beds of siliceous or cherty stone, 4 feet thick, one of which

is a fissile slate more than half made up of siliceous sponge-spicules (curved, straight, and forked) and siliceous casts of minute Foraminifera of the genera *Textularia, Nonionina, Triloculina, Rosalina* (a species near to, if not identical with, *R. Beccarii*). This peculiar siliceous schist or tripoli is of very slight specific gravity. Some silicified Wood and remains of Chelonians have also been found in the associated stony layers at Dieghem.

Beneath this siliceous schist, sands, 40 feet thick, with twenty-five layers of *grès lustré* or grotto-stones, occur. The quantity of stone in nodules seems to increase as we proceed northwards from Brussels, but scarcely any fossils are found in it.

[6.] *Cerithium giganteum.*

This shell has been obtained from Afflighem, near Assche (see Map, fig. 1, Pl. XVII.), N.W. of Brussels, from a quarry no longer open, which formerly furnished building-stone for the construction of a neighbouring abbey. In the same stone are seen *Lucina mutabilis, Turritella intermedia,* and *Nautilus Burtini.* Whether its position was in II. of Table XII. (the *Nummulites lævigatus* division) or in III., I could not ascertain.

3. *Sands with Nummulites planulatus. Lower Nummulitic; Middle Eocene.* (E. 3, Table I. p. 279, & IV. *a*, Table XII. p. 334.) *Système Ypresien, étage supérieur,* of M. Dumont.

[1.] *Lower Nummulitic in the neighbourhood of Brussels.*

The only spot near Brussels, where I saw several bands of stone, consisting of an aggregate of *Nummulites planulatus,* exposed in a natural section, was about three miles south of the city, near Forêt, in a deep lane near the country-seat of M. Musselman (see Section, fig. 8. I. p. 336, and Map, fig. 3. I. Pl. XVII.). I examined this section with Capt. Le Hon, and we observed there within a very short distance all the strata from the lower nummulite-beds (*N. planulatus*) to the Laeken sands inclusive. At the bottom of the lane several layers of stone are seen, containing casts of *Cardium, Cytherea,* and other shells, which appear to underlie the nummulite-bed. But this part of the section is obscure, and there are signs of disturbance, as if a fault had brought down some strata higher in the series to the level of the Lower nummulitic rock. The *Nummulites planulatus* extends through a thickness of about 10 feet of sand, in part glauconiferous, and in the midst of which are some solid bands of aggregated Nummulites. At a higher level the calcareous sands (III. *a*, Table XII.) are distinctly seen, then the *Nummulites lævigatus* bed, separated by a thickness of 70 feet of strata from the lower sandy and stony deposits containing *N. planulatus.* All the beds have a decided dip, and are inclined at a steeper angle than any other which I saw round Brussels. At a higher elevation, in the road from Forêt to St. Gilles, the greenish sands of the lower part of the Laeken beds occur with *Nummulites variolarius* and other fossils before enumerated, p. 335.

I have before stated that in the quarry at Schaerbeek an Artesian

well was excavated, beginning in the "grotto-stones" (III. *b*.) and reaching, at the depth of 70 feet, the bed with *N. planulatus*, below which water was obtained. There seems to be an average thickness of about 100 feet of strata between the two nummulite-beds and II. *b*. and IV. Table XII., but it is very variable. It may be well to remark here, that all the fossils figured by Burtin in his 'Oryctographie de Bruxelles,' 1784, were obtained within these limits, or between the gravel containing *N. lævigatus* and the continuous bands of rock with *N. planulatus**.

In the lowest part of the suburbs of Brussels, near the Pont Léopold, several wells have been sunk, at about 20½ metres or 67 English feet above the level of the sea. They passed, first, through alternations of clay and sand (*N. planulatus* or *Ypresien* division?), continuing to the depth of 50 metres, or 165 feet, below which they came to a mass of clay (London clay proper?, see Section, fig. 8, p. 336), with a thickness of from 20 to 30 metres (65 to 100 English feet). About 200 feet below the level of the sea they reached the White Chalk with flints, there being, as usual, a parting layer between the tertiary and secondary series containing rolled flints with a green coating. The exact age of the beds here pierced I could not ascertain, as no fossils had been collected.

Before concluding my remarks on the environs of Brussels, I have thought it useful to insert a list or synoptical Table of the organic remains which have been mentioned in the preceding pages, distinguishing those found in the Laeken beds as an "upper" division, and those occurring in strata below (Upper and Lower Brussels Sands), as a "lower" division, but not including the *Nummulites planulatus* rock. In the same Table I have introduced (as mentioned p. 331) the fossils from the Hill of Cassel, divided in like manner into—1st, those above the level of the stratum abounding in *N. lævigatus*, and 2ndly, those below. I was not able in either of these districts to obtain sufficient information respecting the division containing *N. planulatus*, to add a separate column for its characteristic organic remains.

For the Brussels lists I am indebted chiefly to Capt. Le Hon, who enabled me to compare a large number of his species with British fossils. The Cassel shells were collected by myself, and named, as already stated, with the aid of MM. Nyst, Morris, and others.

The last column indicates the localities where the same species occur in England or France. In cases where I was acquainted with an English locality I have not inserted "Calc. gross.," Mr. Prestwich having shown the close affinity between the fossil fauna of Barton and Bracklesham and that of the *Calcaire grossier*, including the *sables moyens* as its upper division.

* Mr. T. Rupert Jones informs me that the Nummulite figured as *N. elegans* in the 'Mineral Conchology' from specimens marked "Emsworth, near Chichester," and which Mr. J. de C. Sowerby has kindly permitted him to examine, is (as suggested by M. d'Archiac, 'Hist. Prog. Géol.' vol. iii.) undoubtedly the *N. planulatus* of continental geologists. It is probable, therefore, that in that part of England where the Bracklesham beds with *N. lævigatus* are so largely developed, strata characterized by *N. planulatus* also exist; and it is highly desirable that their relative position should be carefully studied.

Table XIII.

Middle Eocene Fossils from Cassel, near Dunkirk, and from Brussels.

[In the last column of this Table, B. means Barton; Br., Bracklesham; L., London Clay proper; Calc. gr., *Calcaire grossier*; Sab. m., *Sables moyens*, or the upper part of the *Calc. gross.*; Sab. inf., *Sables inférieurs* with *Num. planulatus*.]

	Cassel.		Brussels.		Other localities.
	Upper.	Lower.	Upper.	Lower.	
Nipadites Burtini, *Ad. Brongn.*	•	...	...	•	L.
N. turgidus, Bowerb.					
N. giganteus, Bowerb.					
—— lanceolatus, *Bowerb.*	...	...	...	•	L.
—— Parkinsonis, *Bowerb.*	...	...	...	•	L.
Honium Bruxelliense, *Lyell*	...	...	...	•	
Nummulites lævigatus, *Lamk.*	...	•	...	•	Br.
—— scaber, *Lamk.*	...	•	...	•	Calc. gr.
—— variolarius, *Lamk.*	•	...	•	...	B.?; Sab. m.
Orbitolites complanatus, *Lamk.*	...	...	...	•	Calc. gr.
Operculina Orbignyi, *Gal.*	...	...	•		
Miliolites	...	...	•		
Triloculina	...	...	...	•	
Textularia	...	...	...	•	
Nonionina	...	...	...	•	
Rosalina Beccarii ?, *Linn.*	...	...	...	•	
Caryophyllia multistellata, *Nyst*	...	...	•		
Diphelia, M.-Edw. and J. Haime.					
Turbinolia elliptica, *Brongn.*	...	...	•	...	Calc. gr.
—— crispa, *Lamk.*	...	...	...	•	Calc. gr.
—— Nystiana, *Haime*	•	•	•		
T. sulcata, Nyst.					
——, sp. nov.?	...	...	•		
Idmonea triquetra, *Gal.*	...	...	...	•	
Dactylopora	...	...	•		
Flustra contexta?, *Mich.*	...	...	...	•	
Lunulites radiatus, *Lamk.*	•	...	•	•	Calc. gr.
——, another species	...	•			
Lichenopora	...	...	...	•	
Cellepora? petiolus, *Lonsd.* (Dixon)	...	...	•	...	Br.
Goniaster, fragments	•	...	...	•	Calc. gr.?
Asterias poritoides?, Desm.					
Cidarites?, sp. nov.	...	...	...	•	
Echinolampas affinis?, *E. Forbes*	•	...	...	•	Calc. gr.
Clypeaster affinis?, Goldf.					
—— Galeottianus, *E. Forbes*	•				
—— Dekini, *E. Forbes*	...	...	...	•	
Galerites Dekini, Gal.					
Nucleolites approximatus, *Gal.*	...	...	...	•	
Lenita patelloides, *E. Forbes*	...	•	...	•	
Nucleolites patelloides, Gal.					

TABLE XIII. (continued).

	Cassel.		Brussels.		Other localities.
	Upper.	Lower.	Upper.	Lower.	
Scutellina rotunda, *E. Forbes*	...	...	...	•	
Nucleolites rotundus, Gal.					
Echinocyamus propinquus, *E. Forbes*.....	...	...	•	•	
Echinoneus propinquus, Gal.					
Spatangus Omalii, *Gal.*	...	...	...	•	B.
Terebratula Kickxii, *Gal*.....	•	•	...	•	
Crania Hoëninghausii, *Michel*.....	...	...	...	•	
Clavagella tibialis, *Desh.*	•	...	...	...	Calc. gr.
—— coronata, *Desh.*	•	...	...	...	B.
Gastrochæna	...	•	...	•	
Solen	...	•			
Solecurtus parisiensis, *Desh.*	...	...	•	...	Br.; Calc. gr.?
Panopæa intermedia?, *Sow*.....	...	•	...	...	L.
Corbula gallica, *Lamk.*	•	•	•	•	Br.
—— pisum, *Sow.*	•	...	•	...	B.
—— longirostris, *Desh.*	...	...	...	•	Br. B.
—— umbonella, *Desh.*.....	...	...	•	•	Sab. m.
Thracia?.....	•	•			
Mactra semisulcata, *Lamk.*	...	•	...	•	Calc. gr.
—— depressa?, *Desh.*	...	...	...	•	Br.
Crassatella trigonata, *Lamk.*	...	...	•	...	Calc. gr.
—— plicata, *Sow.*	...	...	•	...	B. Br.
—— compressa, *Lamk.*	...	...	•	...	Br.
C. Nystiana, D'Orb.					
C. tenuistriata, Desh.					
Sanguinolaria Hollowaysii, *Sow.*.....	•	...	...	...	Br.
Psammobia	...	•			
——, nov. sp.	...	...	•		
Tellina sinuata?, *Lamk.*	•	...	...	...	Calc. gr.
—— rostralis, *Lamk.*	•	...	•	...	Br.
—— textilis, *Edwards* (Dixon, pl. 3. fig. 1)	...	...	•	...	Br.
—— tenuistriata, *Desh.*	...	...	...	•	Br.
——, sp. nov.	...	...	...	•	Br.
—— plagia, *Edwards* (Dixon, pl. 3. fig. 5)	...	...	•	...	Br.
—— speciosa, *Edwards* (Dixon, pl. 3. fig. 2)	...	...	•	...	Br.
Lucina divaricata?, *Lamk.*	•	•	...	•	B.
—— mutabilis, *Lamk.*	•	•	...	...	Calc. gr.
—— contorta?, *Def*.....	•	...	...	...	Sab. inf.
—— saxorum, *Lamk.*	...	...	•	...	B. Br.
L. mitis, Sow.					
—— Galeottiana, *Nyst*.....	...	...	•		
—— sulcata, *Lamk.*.....	...	...	...	•	Calc. gr.?
—— gibbosula, *Lamk.*.....	...	...	...	•	Calc. gr.
Cytherea nitidula?, *Lamk.*	...	...	•	...	Br.
—— lævigata?, *Lamk*.....	•	•	•	•	B.
—— suberycinoides, *Desh.*	•	•?	•	•	B. Br.
—— sulcataria, *Desh.*	...	...	•	...	B. Br.
Venus elegans?, *Sow.*	•	...	...	...	Calc. gr.
Astarte Nystiana, *Nyst*.....	...	...	•		
Cypricardia pectinifera, *Sow.*	•	...	•	...	B.

TABLE XIII. (continued).

	Cassel.		Brussels.		Other localities.
	Upper.	Lower.	Upper.	Lower.	
Isocardia, sp. nov.	...	...	•		
Cardium porulosum, *Brander*	•	•	...	•	B. Br.
——, like *C. discors*, Lamk.	...	•			
—— semi-granulatum, *Sow.*	•	•	•	...	B. Br.
—— obliquum, *Desh.*	•	...	...	...	Calc. gr.
—— turgidum, *Brander*	•	...	...	...	B.
——, nov. sp.	...	...	•		
——, nov. sp.	...	...	...	•	
Cardita planicostata, *Lamk.*	...	•	...	•	Br.
—— decussata, *Lamk.*	...	•	...	•	Calc. gr.
—— elegans, *Lamk.*	•	...	•	...	Br.
—— acuticosta, *Desh.*	...	...	•	...	Br.
Nucula margaritacea, *Lamk.*	•	•	•	...	B. Br. L.
—— lunulata, *Nyst*	...	...	•	...	Calc. gr.? } Senlis. }
—— striata, *Lamk.*	•	...	...	...	Calc. gr.
—— (Leda) Galeottiana, *Nyst.*	•	•	•	...	Calc. gr.
Pectunculus pulvinatus, *Lamk.*	...	...	•	...	Br.
P. Nystii, Gal.					
Pectunculus	...	•			
——, a small species	...	...	...	•	
Trigonocœlia (Limopsis) auritoides, *Nyst.*	...	...	•		
Stalagmium Nystii, *Gal.*	...	...	•		
Pectunculus granulatoides, Gal.					
Arca barbatula, *Lamk.*	...	...	...	•	B. Br.
Modiola?	...	...	•		
Pinna margaritacea, *Lamk.*	...	...	•	•?	B. Br.
P. affinis?, Sow.					
Pecten corneus, *Sow.*	•	...	•	•?	B. Br. L.
—— plebeius, *Lamk.*	•	...	•	•	Calc. gr.
—— imbricatus, *Desh.*	•	...	•	...	Calc. gr.
—— sublævigatus, *Nyst*	...	...	•		
—— scabriusculus?, *Mat.*	•				
—— reconditus, *Brander*	•	...	...	...	B.
Spondylus, sp. non det.	...	...	...	•	
Anomia lævigata, *Sow.*	•	...	•	•	B. Br. L.
Ostrea virgata, *Goldf.*	•	•	...	•	B. Br. L.
—— flabellula, *Lamk.*	•	•	•	•	B. Br. L.
O. Cymbula, Lamk.					
—— inflata, *Nyst*	•	...	•?	•	
—— cariosa, *Desh.*	...	...	...	•	Calc. gr.
—— gigantea, *Brander*	...	...	•	...	B.
—— gryphina, *Desh.*	...	...	•	...	Sab. m.
Dentalium substriatum, *Desh.*	...	...	•	...	Calc. gr.
—— incrassatum, *Sow.*	•	•		•	Calc. gr.
D. Deshayesianum, Gal.					
D. strangulatum, Desh.					
Calyptræa trochiformis, *Lamk.*	...	...	...	•	B. Br. L.
Vermetus bognorensis?, *Sow.*	...	•	...	...	L.?
Bifrontia serrata, *Desh.*	...	•	...	...	Calc. gr.

TABLE XIII. (continued).

	Cassel.		Brussels.		Other localities.
	Upper.	Lower.	Upper.	Lower.	
Bifrontia marginata, *Desh.*	...	...	•	...	Calc. gr.
Solarium (Vermetus) Nystii, *Gal.*	•	...	•		
—— trochiforme, *Desh.*	...	...	•	•	Br.
—— grande, *Nyst*	...	...	...	•	
—— patulum, *Lamk.*	...	...	...	•	B.
Phorus parisiensis?, *D'Orb.*	...	•	...	...	Calc. gr.
—— umbilicaris, *Brander*	...	...	...	•	B. Br.
Scalaria spirata, *Gal.*	...	...	•	...	Br.
—— subcylindrica, *Nyst*	...	...	•		
—— ——, var.?	...	...	...	•	
——, sp. nov.	...	...	•		
Turritella edita, *Sow.*	•	...	...	...	B.
—— imbricataria, *Lamk.*	•	•	...	...	B.
—— brevis, *Sow.*	...	...	•	...	B.
T. granulosa, Gal.					
—— terebellata, *Lamk.*	...	...	...	•	Br.
Melania marginata, *Lamk.*	...	•	...	...	Calc. gr.
Tornatella, sp. non det.	...	...	...	•	
——, nov. sp.	...	...	•		
Stomatia, sp. non det.	...	•			
Natica spirata, *Desh.*	...	...	...	•	Calc. gr.
—— patula, *Desh.*	•	•	...	•	B. Br.
—— sigaretina, *Lamk.*	•	...	...	•	B.
—— epiglottina, *Lamk.*	...	...	...	•	Calc. gr.
—— labellata, *Lamk.*	...	...	...	•	B. Br. Cal. gr.
—— glaucinoides, *Desh.*	...	...	•	...	B. Br. L.
—— ambulacrum, *Sow.*	•	...	...	...	B.
Globulus, Sow.					
—— parisiensis, *D'Orb.*	...	•	...	...	Calc. gr.
Sigaretus canaliculatus, *Sow.*	...	•	...	•	B. Br.
Bulla lignaria, *Linn.*	...	...	•	...	B.
—— expansa, *Dixon*	...	...	•	...	Br.
—— Bruguierei, *Desh.*	...	...	•	...	Calc. gr.
——, sp. non det.	...	...	...	•	
——, ——	...	...	...	•	
Bullæa, sp. nov.	...	...	•		
Fusus ficulneus, *Lamk.*	...	...	...	•	B. Br.
—— bulbiformis, *Lamk.*	...	•	...	•	B. Br. L.
—— errans, *Sow.*	...	...	...	•	B. Br.
—— aciculatus?, *Lamk.*	...	...	•	...	B. Br. L.
Murex porrectus, Brander.					
—— elongatus, *Nyst*	...	...	...	•	
—— longævus, *Brander*	...	...	•	...	B. Br.
F. scalaris, Lamk.					
Pleurotoma, sp. non det.	...	•			
——?	...	...	•	•	
Cerithium giganteum, *Lamk.*	•	...	•?	...	Br.
——, allied to *C. reticulatum*, Risso					
——?	...	...	...	•	
Murex tricarinatus, *Lamk.*	...	...	...	•	B. Br.

TABLE XIII. (continued).

	Cassel.		Brussels.		Other localities.
	Upper.	Lower.	Upper.	Lower.	
Cassidaria carinata, *Lamk.*	*	...	...	*	B. Br. L.
—— nodosa, *Nyst*	*	...	...	*	B.
Buccinum nodosum, Brander.					
——, sp. nov.	...	...	...	*	
Rostellaria macroptera, *Lamk.*	...	*	...	*	B. Br. L.
—— fissurella, *Lamk.*	...	*	...	*	B. Br.
Pyrula, sp. non det.	...	...	...	*	
Buccinum stromboides, *Herm.*	...	*	...	*	Br.
—— junceum, *Sow.*	*	...	...	...	B.
Conus deperditus?, *Brug.*	...	*	...	*	Br.
—— antediluvianus?, *Brug.*	*	...	...	...	Calc. gr.
—— turritus, *Lamk.*	...	...	...	*	Calc. gr.
Ancillaria	...	...	...	*	
Voluta cithara, *Lamk.*	...	...	...	*	Br.
Oliva, sp. non det.	...	...	...	*	
Terebellum, sp. non det.	...	*			
—— convolutum, *Lamk.*	...	*	...	...	B.
Seraphs convolutus, Montf.					
Nautilus Burtini, *Gal.*	*	...	...	*	L.?
N. regalis?, Sow.					
Sepia Cuvieri, *Desh.*	...	...	*	*	Calc. gr.
Beloptera?	...	...	*	*	
Serpula, sp. nov., allied to *S. triquetra*, Lamk.	...	...	*		
Cancer Burtini, *Gal.*	...	...	...	*	
——, sp. non det.	*				
Cœlorhynchus rectus, *Agas.*	...	...	...	*	
Œtobates, sp. non det.	...	...	...	*	
Pristis (Dixon, pl. 10. fig. 36.)	...	...	...	*	Br.
—— Lathami, *Gal.*					
——, nov. sp.					
Myliobates striatus, *Ag.* (Dixon, pl. 12. fig. 2.)	...	...	...	*	Br.
—— Dixoni, *Ag.* (Dixon, pl. 10. fig. 2 & pl. 12. fig. 3)	...	...	...	*	Br.
——	...	...	...	*	
Lamna	*				
—— elegans, *Agas.*	...	*	...	*	L.
Otodus obliquus?, *Agas.*	...	...	...	*	L.
—— macrotus, *Agas.*	...	*	...	...	L.
Edaphodon Bucklandi, *Ag.* (Dixon, pl. 10. fig. 21)	...	...	...	*	Br.
Zeus armatus, *Blainv.*	...	...	...	*	
Pleuronectes maximus, *Blainv.*	...	...	...	*	
Ear-bone of Fish?	...	...	...	*	
Emys Cuvieri?, *Gal.*	...	...	...	*	
Gavialis Dixoni, *Owen* (Dixon, pl. 12. fig. 4)	...	...	...	*	Br.

The results of most value deducible from the above Table are those suggested by the fossil Mollusca. The total number of these enumerated is 157, but some of them can only be determined generically from casts, and others are new and as yet undescribed. The number of named species is 122, and no less than 106 of these are common to the Eocene beds of England and France; 102 being of the age of the Barton and Bracklesham beds of England or the corresponding *Calcaire grossier* of France, while only four belong exclusively to the London Clay proper or to the *Sables inférieurs* of France. The identity, therefore, of this portion of the Cassel and Brussels tertiary series with the British Middle Eocene group is very striking. In regard to the unnamed fossils, some of them are probably peculiar to French Flanders and Belgium, but most of them might be identified with British species, if we had the means of comparing them in London with large numbers of English Eocene fossils still undescribed.

The next result worthy of notice is derived from the "Upper Brussels" column relating to the shells, obtained, chiefly by the exertions of Capt. Le Hon, from Laeken, Jette, and other localities of the same "Upper Nummulitic" strata near Brussels. These species, belonging to what has been termed by M. Dumont the *Système Laekenien*, are sixty-five in number, eighteen of which are at present peculiar, but I have no doubt that this proportion might easily be reduced, inasmuch as the researches of the late Mr. Dixon in the Eocene deposit of Bracklesham, near Chichester, have brought to light many Mollusca and Bryozoa identical with Laeken fossils. Out of fifty-seven named Laeken shells, no less than forty-four are common to the *Calcaire grossier*, or beds of the same age in England. Such being the case, we have no reason to feel surprised that the fossils of the ferruginous sands of Mont Noir, near Cassel, which overlie strata corresponding in age to the Laeken beds of Brussels, should nevertheless contain shells which agree with the Bagshot and Bracklesham fauna of England. In other words, the *Système Laekenien* is simply one of several upper divisions of the *Calcaire grossier*.

It may, at first sight, seem strange that there are not more species common to the Cassel and Brussels lists, only thirty-two named species being common out of a total of 122; also that in each district so few species are common to the upper and lower divisions, at Cassel only sixteen out of sixty-two named species being common to the upper and lower series, and at Brussels only fifteen out of ninety-two species. How are we to reconcile such a result with the fact that each of these sets of fossils, when compared to the *Calcaire grossier* or Middle Eocene of England and France, exhibits nearly an equal amount of identity? The apparent inconsistency is, I think, removed when we recollect that each of the asterisk columns of Table XIII. represents a mere fraction of a great fauna obtained from the Middle Eocene beds of the south-east of England or from the Paris Basin. The analogous degree of relationship of the Cassel and Brussels fauna to one and the same foreign equivalent shows that they would

each approximate much nearer to each other, if we were able to extend our knowledge of the fossils of the respective districts; although there would still remain some distinctions arising from variations of species in space or in time; the representation of each precise stage, or division in time, of the fossils of the same Middle Eocene group being always imperfect, and usually unequally so in the several countries compared. The small number common to the "upper and lower Brussels" beds, or to the upper and lower Cassel beds, *i. e.* to the Upper and Middle Nummulitic, is no doubt in part the effect of change of species in time, and corresponds to the distinction between the Barton beds and the lower Bagshot (or lower Bracklesham) in England, or that of the *Sables moyens* (*grès de Beauchamp*) and the *Glauconie grossière* in France.

The number of Plants, Zoophytes, and Vertebrata common to the different divisions, or to the two districts, is too small to require me to dwell upon them. So far as they go, they coincide in their bearing with the conclusions to which we are led by the fossil Mollusca.

[2.] *Middle Eocene strata near Mons. Mont Panisel.*

It is well known that in the neighbourhood of Mons (about thirty-five English miles S.S.W. of Brussels) the Maestricht chalk is seen at Ciply, and above it are sands and clays (at Chasse Royale and other places), referred to the *Système Landenien* of Dumont. At a higher level, strata containing *Nummulites planulatus* in abundance have been found in wells sunk in the city of Mons. I found the same Nummulite in Mont Panisel, in the suburbs, sparingly dispersed through beds of clay and in greenish and yellowish ferruginous sands in which were some cherty beds containing casts of fossils with silicified shells. I examined Mont Panisel in company with M. A. Vroilliez and M. Ch. De Beaulieu, and with their assistance obtained the following fossils:—

Nummulites planulatus.	Tellina.
Pinna margaritacea; abundant.	Nucula.
Loripes divaricata,	Crassatella.
Cardium porulosum?	Astarte.
Cassidaria nodosa.	Cardita.
Natica patula?	Fusus.
Lucina gibbosa.	Voluta.
Solen.	

These seem to be inferior to the Brussels Beds, of which the fossils are enumerated in the "Lower Brussels" column of Table XIII.

[3.] *Renaix, Craye, and Audenaerde.*

From the hills of Renaix, Mont Panisel above-mentioned may be seen. Near Renaix, about two miles S.E. of the town (see Map, Pl. XVII.), the stony beds with *Nummulites planulatus* are exposed to view in the bed of a small brook, where they are associated with clays and sands. The locality alluded to occurs in the Commune of St. Sauveur, on the farms of Tombelles and Arabie, where I was

conducted to a fine section by M. E. Joly, Advocate, well known for his antiquarian researches. Beds of clay, alternating with greenish sands and brick-earth, cover the solid layers of Nummulite-limestone to a thickness of 100 feet, and among them occur indurated siliceous sandstones similar to those in Mont Panisel, before-mentioned, with chalcedonic casts of shells, *Pinna margaritacea* being very abundant. The following fossils, collected by myself, or given me by M. Joly, are from this place or from Ellezelles near Renaix :—

Turbinolia sulcata, *Lamk.*
Solen.
Corbula, cast.
Tellina donacialis ?, *Edwards.*
Tellina.
Cytherea, near *C. obliqua*, Desh.
——, near *C. nitidula* ?, Lamk.
Cardita planicostata, *Lamk.*
Nucula margaritacea, *Lamk.*
Pinna margaritacea, *Lamk.*
Pecten.
Ostrea flabellula, *Lamk.*
Turritella imbricataria, *Lamk.*
Natica, allied to *N. Hantoniensis*, Sow.
Natica.
Fusus longævus, *Lamk.*
Pleurotoma.
Rostellaria fissurella, *Lamk.*
Cassidaria carinata, *Lamk.*
Voluta luctator ?, *Sow.*
——, two other species.
Terebellum.
Cypræa.
Nautilus, cast.
Cancer Leachii ?, *Desm.*
Xanthopsis, M'Coy.

At Kraye (or Craye), to the N.W. of Renaix, on a road leading from Renaix to Berchem on the Scheldt, I found sands with dispersed specimens of a variety of *Nummulites planulatus*, about 150 feet higher in the series than the solid beds at the farm of Arabie before-mentioned. These upper grey sands with green grains contain in great abundance an orbicular variety of *Cardita planicostata*, with *Cardium porulosum*, *Corbula*, &c.

At Audenaerde I observed beds similar to those of Renaix and Mont Panisel, the *Pinna margaritacea* being abundant in cherty beds which are sometimes used for pavement.

[4.] *Courtray.*

Three miles south of Courtray I found a tertiary clay, extensively worked for brick-making, which abounded in *Nummulites planulatus* in a very perfect state of preservation. I was directed to this region as likely to afford fossil remains by M. Dumont. The clay of Courtray evidently belongs to the Lower Nummulitic division, E. 3 of Table I. p. 279.

The fossils which accompanied the Nummulites, including a *Turritella* and some others, were too imperfect to admit of being specifically determined.

[5.] *Ghent.*

About three miles south of Ghent, at the country-house of M. P. Loozberg, an artesian well had been sunk to the depth of 70 metres at the time of my visit. The upper 35 metres consisted of sandy and clayey glauconites, with *Nummulites planulatus* dispersed through them at several levels. In examining this Glauconite Mr. Rupert Jones has lately found a few specimens of two species of Entomostraca, viz. *Cythere angulatopora*, Bosq., and *Cytherella Munsteri*,

Rœm. sp., both which (according to M. Bosquet*) occur in the Eocene strata of France. The lower half was made up of stiffer clay of a bright green colour, and lower down of darker colour, in which I found no Nummulites. As the Brussels beds with *Nautilus Burtini* occur in the trenches of the citadel at Ghent, I imagine the green sands of this well to belong to E. 3 of Table I., or the *Système Ypresien* of M. Dumont. It may perhaps be found possible and convenient to draw here and elsewhere a line of demarcation between the Ypres beds and the London Clay proper at the point where the Nummulites cease. Whether the beds containing *N. planulatus* near Ghent or Courtray may correspond in age with an upper division of the London Clay proper, or with the lowest part of the Bagshot series, cannot as yet be decided.

[6.] *Mons-en-Pevelle, near Lille.*

At no locality visited by me were the bands of Nummulitic limestone so conspicuous as at Mons-en-Pevelle, about nine miles south of Lille, to which my attention was directed by M. Meugy. The thickness of the formation (overlying the London Clay) to which they belong is estimated by that geologist at about 100 feet. I saw the layers of nummulitic rock, from 6 to 8 inches thick, extending throughout a thickness of about 60 feet of sandy and clayey beds. Not only were the roads made of them, but several buildings were in part constructed of the same, and I saw the yard of a farm-house paved with nummulitic slabs. With the exception of a *Dentalium* (*D. Deshayesianum*), I could find no fossils in the associated strata. In this part of French Flanders the lower nummulitic beds are separated from the Chalk by about 150 feet of London Clay, and nearly 100 more of Plastic clay and sand.

§ 8. *London Clay proper* (F. 1. Table I.). *Argile Ypresien, étage inférieur,* Dumont.

I have already stated, p. 331, that at the railway-station at Cassel a mass of brown clay with septaria was bored to the depth of 100 metres, and the bottom not reached. In uniformity of aspect it resembled the clay of Highgate and other places near London, and the absence of shells in the large heaps of clay extracted from the well, which I examined carefully, might be paralleled by a similar dearth of fossils in numerous sections in the London and Hampshire basins. The green sands and clays above the London Clay in the Hill of Cassel much resemble those containing *Nummulites planulatus* elsewhere, although I could not meet with that fossil at Cassel.

Near Lille a mass of clay, estimated by M. Meugy to be about 44 metres (or 145 feet) thick, underlies the *Nummulites planulatus* sands and limestone of Mons-en-Pevelle already described, and under that again are sands and clays, probably corresponding to the Plastic

* Descript. des Entom. Foss. des Terrains Tertiaires de la France et de la Belgique, Mém. Couron. Acad. Roy. Belg. vol. xxiv.

clay and sand near London. No progress seems yet to have been made here or elsewhere in obtaining fossils from the *argile Yprésien*, whether in French Flanders or Belgium. In the latter country this clay appears to be feebly developed, or usually wanting, as in the Paris basin.

At Bailleul, between Cassel and Lille (see Map, Pl. XVII.), many shells were met with in boring a well through this clay, but they were not preserved.

At Brussels, a mass of clay, lying over the Chalk and about 80 feet thick, was found in boring wells. It is separated from the chalk, as before stated (p. 350), by a band of flint-pebbles coated with green earth. There are not sufficient data as yet for deciding whether part of this clay should be referred to the London Clay proper.

§ 9. *Plastic Clay, Sand, and Lignite* (F. 2. Table I. p. 279). *Système Landenien supérieur*, Dumont. *Lower London Tertiaries*, Prestwich.

1. *Carvin, near Lille.*

Below the London Clay near Lille are sands and clays, about 80 feet thick, which resemble the beds near London usually called "Plastic clay and sand." The only fossils as yet found in them are marine, and occur in a clay, not more than 25 or 30 feet above the chalk. M. Meugy took me to the junction of the chalk and tertiary strata at Carvin, twelve miles south of Lille (see Map, Pl. XVII.). Within 300 yards of the church of Carvin we saw an open well just dug, where the White Chalk with flints appeared within 10 feet of the surface. Upon it there was no parting band of pebbles, but, in contact, schistose sandy clay, greenish but not glauconiferous, with a few well-rolled black pebbles interspersed. This clay or loam was 10 feet thick. At a short distance, and no doubt incumbent on the above, a tenacious clay occurs, several feet thick, which is worked for pottery; and above this again, in another pit, the sandy clay with concretions in which shells abound. Among these the *Cyprina Morrisii*, Sowerby ('Min. Con.' vol. vii. p. 20, pl. 620), abounds, which is characteristic of the Plastic Clay near London, and a *Turritella*, *Arca*, and *Corbula*, in casts too imperfect to admit of being specifically determined. There are white sands with some solid beds of sandstone in them near Lille, between the clay with *Cyprina Morrisii*, above-mentioned, and the London Clay, but I saw no good sections.

2. *Jauche, Huppaye, Oplinter, &c.*

In Belgium, above the "Lower Landenian," which I shall presently describe, and below the Brussels beds with *Nummulites planulatus*, there occurs a formation of sand, siliceous paving-stone, and lignite, to which the name of *Landenien supérieur* has been given by M. Dumont. As no fossil shells have been found in it, I cannot identify it palæontologically with that part of the British Tertiaries with which it may probably be contemporaneous. I saw its super-

position to the Lower Landenian near Jauche, on the road leading to Enines (Map, fig. 2, Pl. XVII.), where it is 40 feet thick, and consists of alternating yellow and whitish sands, resembling the "striped sands" of Lewisham and Woolwich, and, like the British "Lower Tertiaries," containing a bed of lignite. At a higher level in the series, at Huppaye, in the same district, this formation contains snow-white sands with beds of hard paving-stone or siliceous sandstone, from 7 to 10 feet thick. I saw the same "striped sands" at Marilles, about one league north-east of Huppaye, traversed by a layer of well-rounded flint-pebbles. In the neighbourhood of Tirlemont I found fragments of silicified wood in this part of the series, and at Oplinter, a few miles north of Tirlemont, clay with lignite and the leaves of dicotyledonous trees. To this locality I was conducted by M. de Koninck. M. Dumont informed me that, at some points, the alternations of clay and beds of lignite in the middle portion of this series are very numerous. We may hope, therefore, that some fossil plants, at least, may hereafter be obtained.

Near the railway station at Landen I saw a section of the upper Landenian formation, consisting of white and yellow striped sands without fossils, about 35 feet thick.

§ 10. *Glauconite of Tournay and Angres* (G. Table I. p. 279). *Beds between the Plastic Clay and the Chalk of Maestricht. Système Landenien inférieur*, Dumont.

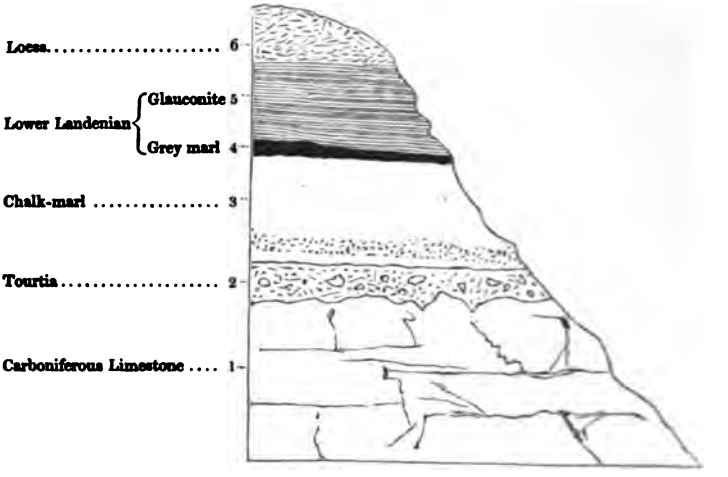
I have next to describe strata which are certainly older than those last alluded to, but concerning the relations of which to the Tertiary or the Cretaceous series, much difference of opinion exists. The localities where I examined this series, called "Lower Landenian" by M. Dumont, were:—1. Tournay. 2. Angres, near Quiévrain, about fourteen miles S.W. of Mons: see Map, fig. 1, Pl. XVII. 3. In the province of Hesbaye, at Folx-les-Caves, Orp-le-Grand, Lincent, and several other places.

1. *Tournay.*

About two miles from the Valenciennes gate of Tournay, on the left bank of the Scheldt, are some large quarries deeply excavated in the Mountain or Carboniferous limestone. In one belonging to M. Dapsens Carbonnel, the limestone (1) is seen covered as in the accompanying section, fig. 10, with a well-known member of the chalk, provincially called "tourtia" (2), above which is white chalk-marl (3), with the usual fossils, upon which rest strata (4, 5), referred by M. Dumont and others to the tertiary series, and called in Belgium "Lower Landenian." The lowest of these is an argillaceous grey marl (4), strongly contrasted in its darker colour with the white chalk-marl. I found in this grey marl (4) a perfect specimen of a well-known chalk fossil, *Terebratula gracilis*, Schlotheim (*T. rigida*, Sow., 'Min. Conch.' vol. vi. p. 69, pl. 536. fig. 2), with both valves united. With this was *Terebratula striatula*, in abundance, also *Ostrea* (*Exogyra*) *lateralis*, Nyst, and a *Bryozoon*.

Reposing on the marl (4) and passing into it at the junction are

Fig. 10.—*Section near Tournay.*



beds of a green sandy glauconite (5) 10 feet thick, in the upper part of which layers of cherty stone from 6 to 8 inches thick abound, with casts of shells. In this glauconite the same *Ostrea lateralis* and *Terebratula striatula* occur which are met with in the grey marl (4), so that it seemed to me impossible to draw a line between the beds "4" and "5," or to consider "4" as cretaceous and "5" tertiary. The other fossils which I found in "5" consisted of a *Pholadomya* (*P. Koninckii* ?), *Cucullæa*, *Pinna*, *Turritella*, *Fusus*, *Natica*, &c., chiefly casts, and these in too unsatisfactory a state to admit of being specifically distinguished. A gigantic *Pleurotomaria*, sometimes retaining its shell, is not uncommon in these beds, and is very unlike any fossil occurring in the Lower Tertiaries of England or France. It resembles rather the *P. gigantea* of the Lower Greensand. One species, and as yet one only, of this genus, is known in the *Calcaire grossier*,—*P. concava* of Deshayes ('Coq. Foss. de Paris,' vol. ii. pl. 32. fig. 1, 2, 3), much smaller in size, though somewhat analogous in form. According to Baron Ryckholt, who possesses the finest collection of shells from the glauconite of Tournay, all the species which have been referred to tertiary shells are distinct. Not a few of them he considers identical with fossils of the Faxoe, Maestricht, and other cretaceous formations. The difficulty of defining the specific characters in the genera *Pholadomya*, *Scalaria*, *Mya*, and *Pinna*, without having a full and perfect series of the individuals for comparison, is such that I cannnot pretend, without better specimens than I brought from Tournay and Angres, to offer a positive opinion on this point. I believe nevertheless that Baron Ryckholt, when he publishes a full account of his valuable collection, will succeed in proving the beds in question to be older than any fossiliferous strata above the Chalk in England.

2. *Angres, near Quiévrain.*

At Angres, near the southern frontiers of Belgium, fourteen English miles south-west of Mons, the White Chalk with flints is covered with a solid glauconite, free from calcareous matter, and full of the casts of shells. I visited this place in company with M. de Beaulieu, Professor of the École des Mines at Mons. We found a section in a hollow way, within half a mile N.N.E. of the church of Angres, where a thickness of 25 feet of thin-bedded and half-solidified glauconite is seen. The stone at some points becomes very hard, and the green grains are larger and more widely scattered in the upper beds. I obtained the casts of about fifteen shells, belonging to the genera

Arca.	Venus?
Cucullæa (allied to *C. decussata*).	Tellina.
Panopæa (like *P. intermedia*?).	Pinna.
Pectunculus.	Ostrea.
Crassatella.	Turritella.
Nucula.	Lucina?
Pholadomya (resembling *P. cuneata*, Sow. M. C. pl. 630).	Natica.
Astarte.	Calyptræa.

Also a Bryozoon (Retepora?) and an Echinoderm.

The casts were many of them decidedly the same as those already mentioned as occurring near Tournay. We afterwards saw a similar glauconite with similar fossils at Baisieux, two miles north of Angres, and about a mile south of Quiévrain.

The matrix of the shells at Angres is sometimes quite undistinguishable from that Middle Eocene glauconite, with large coarse grains of green earth, which occurs at Boeschepe near Cassel, before described, p. 325, and in which casts of a large *Ovula* and other shells occur. It is one of many instances in Belgium of the identity in mineral character of tertiary beds of very different ages, to which the abundance of glauconite particularly contributes.

3. *Folx-les-Caves, Jauche, Jendrain, Orp-le-grand, &c.*

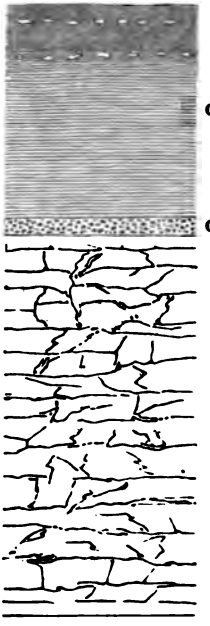
I shall now pass to another part of Belgium (between Brussels and Liege, seventy or eighty miles eastward of Tournay), where strata, also called "Lower Landenian," and probably of about the same age as those of Tournay and Angres already described, are met with in the cantons of Landen, Jodoigne, and Tirlemont. See Map, fig. 2, Pl. XVII.

At Folx-les-Caves, the most southern point where I saw this formation, it rests on the Maestricht Chalk, fig. 11, I, which is there quarried to the depth of 20 feet for building-stone, and exhibits *Belemnites mucronatus* and other characteristic fossils.

The chalk is covered by a bed of rolled flint-pebbles, some of which are 4 inches in their longest diameter. This bed (G. 2), forming the base of the "Lower Landenian," is 1 foot thick, and supports a stratum (G. 1) of soft glauconite, 6 feet thick, the upper part of which is clayey, and contains some small dark concretions, which, like the greensand matrix, are highly calcareous. The fossils in the

glauconite (G. 1) consist chiefly of *Astarte inæquilateralis*, Nyst, well-preserved and often with both valves united. On one of these I found a small attached coral (*Dendrophyllia*). In the same bed a large species of *Dentalium* occurs, and some casts of Bivalves.

Fig. 11.—*Section at Folx-les-Caves.*



ft.

G 1. Glauconite; upper part clayey, with small concretions 6

G 2. Pebble-bed 1

I. Maestricht Chalk ..... 20 exposed.

No other member of the "Lower Landenian" is seen at Folx-les-Caves, but a solid and whitish glauconite, called by Omalius d'Halloy *tufeau de Lincent*, occupying a higher position in the same series, is met with at the distance of three or four miles to the north and west, as at the village of Jauche, where there is a hollow lane in which the whitish tufeau and greenish sand or soft glauconite are seen to attain a thickness of about 20 feet, and greatly to resemble in character some members of the Chalk and Upper Greensand of many parts of Europe. The tufeau is highly calcareous and of small specific gravity, hence it is of cheap carriage and highly useful as a building-stone. Some of the beds are cherty; casts of a small *Nucula* (*Leda*) are most common in the tufeau. In part of the region alluded to, the Lower Landenian rests immediately on White Chalk with flints without the intervention of the Maestricht chalk, as at Jendrain, and sometimes, as in the immediate neighbourhood of that village and on the road from it to Orp-le-Grand, the Maestricht chalk is reduced to a thickness of less than 2 feet between the White Chalk with flints and the overlying Landenian. The Maestricht bed here contains large concretions of silex, more or less pure, and is full of

Thecidea radians and *Belemnites mucronatus*, with *Terebratulæ* and other characteristic fossils; it contains also many rolled pebbles of flint near its junction with the White Chalk. This fact is important, as showing that the White Chalk with flints had suffered denudation previously to the deposition of the Maestricht beds. The occurrence of rolled pebbles at the base of the Maestricht rock is analogous to the pebbly glauconite which separates the Maestricht chalk from the Lower Landenian, so that the parting layer of pebbles, which at Folx-les-Caves might seem, at first sight, to afford good ground for separating the cretaceous and tertiary formations, loses all importance as a line of demarcation. The upheaval and exposure of the secondary rocks had evidently begun before the termination of the cretaceous period.

In the middle of the village of Jendrain above mentioned a chalk-pit has been opened, where the White Chalk with flints is covered immediately by the Lower Landenian containing the wreck of the Maestricht chalk, and its flints or cherty rock, which consist of huge flattened masses, several feet in diameter. At Wanzin (Map, fig. 2. Pl. XVII.), I saw several sections where the surface of the White Chalk had been much denuded, and where the whitish glauconite or tufeau of the Lower Landenian, characterized by *Astarte inæquilatera*, filled up inequalities scooped out of the older rock.

4. *Orp-le-Grand, Pellaines, Lincent, and Amptieau.*

At Orp-le-Grand the light tufeau is quarried for building purposes to a depth of more than 20 feet. One of the most conspicuous fossils, called *Gyrolites* (*Vermiculites* of Nyst), resembles the tubular cavities left by a large boring Annelid, and traverses the stone in curves several inches in diameter. The *Astarte inæquilatera* connects this rock with the glauconite before mentioned of Folx-les-Caves. The *Pholadomya Koninckii*, also abundant, forms a link between it and the glauconite of Tournay, before mentioned, p. 362. With these shells I found a cast and impression of a large *Scalaria*, which appears undistinguishable, so far as a cast will admit of comparison, with a species in Mr. Bowerbank's cabinet from the Lower London Tertiaries or Thanet Sands. The other shells are *Dentalium*, casts of *Cucullæa*, *Arca*, *Nucula*, *Turritella*, *Natica*, and *Pleurotoma*?, with teeth of *Lamna*. I found also two species of Echinoderms, one of them, according to Professor E. Forbes, of the genus *Hemiaster*, a form belonging equally to the cretaceous and tertiary periods; and the other referred to *Cardiaster* by the same authority, who remarks that this genus has hitherto been only met with in *cretaceous* strata. This discovery is interesting in its bearing on the question whether the Lower Landenian fauna has most relationship with a cretaceous or a tertiary type, or whether it be not intermediate in character and in age. No Baculite, Belemnite, Ammonite, or other Cephalopod of a family peculiar to the Chalk, has hitherto been met with in these beds; but the same may be said of the true cretaceous strata in many regions.

I visited Pellaines and Lincent, where magnificent square blocks

and tall columns of the tufaceous building-stone are obtained from the quarries, and the same fossils as at Orp-le-Grand. At Amptiena I found the Lower Landenian passing into a white calcareo-argillaceous rock, much used as a fire-stone, in which I observed *Pholadomya Koninckii* and a small *Leda*, allied to *L. fragilis*. As usual in Belgium, a deep covering of loess renders it difficult to obtain sections.

It may be proper to mention here, that many decidedly Eocene shells have been cited from Orp-le-Grand and the other localities just alluded to, chiefly on the authority of M. Galeotti; but having failed to detect any of them *in situ* here or elsewhere in beds of this age, and having conversed with M. Galeotti himself, I am convinced that they were introduced into the published lists by mistake. These shells have not only been cited from M. Galeotti's memoir by M. Nyst and M. d'Omalius d'Halloy*, but more recently by M. d'Archiac†. Among these spurious fossils are *Nummulites lævigatus*, *Lunulites radiatus*, *Turbinolia sulcata*, *Cytherea nitidula*, *Lucina divaricata*, *Cardium porulosum*, *Cardita elegans*, *Ostrea flabellula*, *Dentalium Deshayesianum*, *Melania marginata*, *Cassidaria carinata*, *Solarium Nystii*, and other Eocene shells, not one of which has ever been met with in the "Lower Landenian" of Dumont.

§ 11. *Marls and Glauconite of Heers* (H. Table I. p. 279). *Système Heersien* of M. Dumont.

Between the formation last mentioned and the Maestricht chalk, there intervenes another series of strata, discovered by M. Dumont, and called by him *Heersien*, from the village of Heers (six miles N.N.E. of Waremme). These are best seen near the village of Oreye, at the farm of Vivier, about six miles N.E. of Waremme, where they consist of white marl, resting on sandy glauconite, and this last on Maestricht chalk.

I had no opportunity of examining this locality, but was conducted to another by M. Dumont at Marlinne, between Waremme and Looz, about fifteen miles E. of Orp-le-Grand, and four miles N. of Waremme, where this formation consisted of a white marl, 20 feet thick, as white as chalk, but not so soft, and containing leaves of dicotyledonous plants, but no shells. It is here seen to underlie the Lower Landenian, which reposes upon it in the form of a glauconite, similar to that of Folx-les-Caves. No progress has yet been made in comparing the species of dicotyledonous leaves with those found in other formations. Their occurrence affords no evidence of the tertiary nature of the Heersian strata, now that Dr. Debey has brought to light in the lower cretaceous beds of Aix-la-Chapelle so great a variety of the leaves of dicotyledonous plants‡.

It is clear, therefore, that there are in Belgium certain deposits, consisting of glauconites and marls, interposed between the Chalk

* Géologie de la Belgique, 1842. † Hist. des Progrès, vol. ii. p. 502, 1848.
‡ Entwurf zu einer Geogn. Darstellung der Gegend von Aachen, 1849. See also Quart. Journ. Geol. Soc. vol. vii. Part II. p. 109.

of Maestricht and beds of the age of the Lower London Tertiaries. The change in Europe from the Maestricht and Faxoe fauna to that of the Lower Eocene is so vast as to prepare us for the discovery of a long series of such intermediate rocks, characterized by species in part new and in part cretaceous or tertiary,—formations in which genera, hitherto regarded, like the *Cardiaster*, as exclusively secondary, and others only known before as tertiary, may be found associated. Instead of grouping all these monuments of an intervening period as Cretaceous or as Eocene, it may be convenient to introduce a new system, to which the *calcaire pisolitique* of France and the Heersian and Lower Landenian of Belgium may be referred.

In the Synoptical Table of tertiary formations, which has been introduced into an early part of this paper (p. 279), it will be seen that, so far as I have been able to ascertain, the Lower Landenian and Heersian groups have no exact equivalents in the British Islands. This opinion may require modification hereafter, when a fuller comparison has been instituted between the Lower Tertiary fossils of England and those of Belgium. In the meantime, the place assigned by M. Dumont to the Lower Landenian will be understood by consulting his Tables already alluded to (p. 279, *note*) and printed as Appendices Nos. I. and II. One of these was published in 1851, and the other appears now for the first time, having been recently communicated by the author, after his return from a geological excursion in England in the autumn of 1851. To him, and to all the other geologists of Belgium with whom I had the pleasure of conferring, I have to express my warmest thanks for their zealous and effective cooperation. I must also avail myself of this opportunity of acknowledging my obligations to MM. Nyst and De Koninck in particular, for their unremitting attentions during my tour, and their instructive correspondence since my return. In several of the principal districts, the reader cannot fail to have perceived that I should have made but little progress in the examination of their palæontology without such assistance as that afforded me at Antwerp by M. Norbert de Wael, at Brussels by Captain Le Hon, and in the Limburg by M. Bosquet. These naturalists have enabled me to present to the scientific world a more complete catalogue of the fossils of the several regions studied by each of them, than had previously been printed; and in each case, when they generously placed at my disposal the ample materials which it had cost them the labour of years to bring together, they asked no other return for the gift than that I should obtain the opinions of the best English palæontologists on their fossils. I have accordingly endeavoured by the aid of several friends, whose names appear frequently in this memoir, especially those of Messrs. S. V. Wood, Morris, Edwards, Rupert Jones, Hooker, and E. Forbes, to discharge the debt incurred to my foreign fellow-labourers; giving the results of their comparison of Belgian and British fossils, respecting which doubt and discussion had arisen, whether in reference to specific characters, or to position in the geological series.

It may also be well to state, before concluding, that, notwithstanding the slight inequalities of level and the rarity of natural sections in a

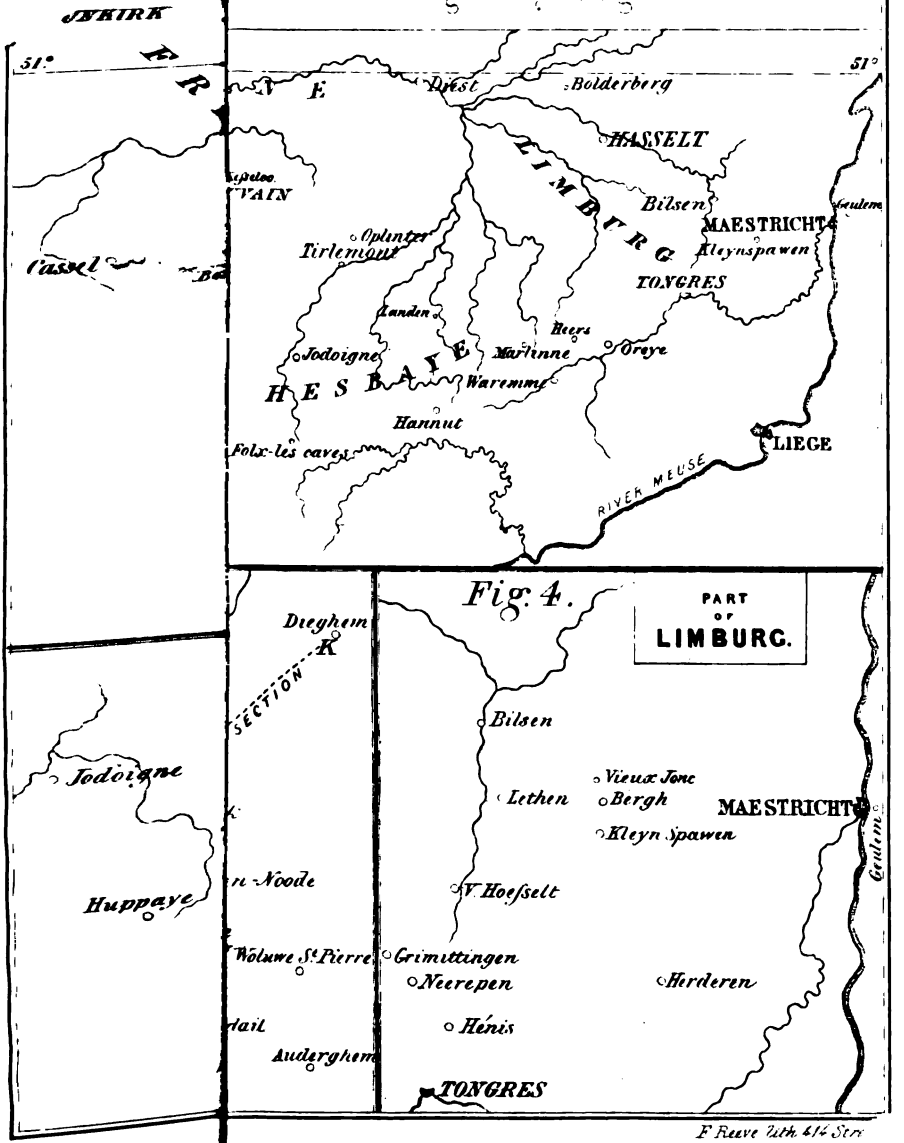
great part of Belgium, no European country of equal area affords a richer, perhaps no one so rich a field for the study of rocks newer than the White Chalk with flints. I have stated in the present memoir, that the older Pliocene or Crag strata of Suffolk are very fully represented at Antwerp, and that in the Limburg the Upper Eocene group is more completely developed than its equivalent in the Isle of Wight. The Bolderberg affords an example of beds intermediate between the two groups last mentioned (probably of the Miocene period), to which nothing similar in age has yet been found in England. Again, the chalk of Maestricht or Ciply, long recognized as an upper and peculiar member of the cretaceous system, is another rock of which we have no example in Great Britain. Last, not least, there have been discovered by M. Dumont and others, near Tournay and in different parts of Hesbaye, strata occupying a position between the Maestricht Chalk and the Lower London Tertiaries. These Lower Landenian and Heersian groups of Dumont promise no scanty harvest to the collectors of organic remains, and may, therefore, soon be made to throw light on a period of the earth's history as yet more obscure than any other of equally modern date. Judging from the character of the numerous publications which have appeared in Belgium during the last fifteen years, we may confidently affirm that the scientific explorers of that country will continue to prove themselves worthy of the grand field of investigation thus thrown open to them.

MAP

OF PARTS OF BELGIUM AND FRENCH FLANDERS

to accompany a memoir

by Sir Charles Lyell.



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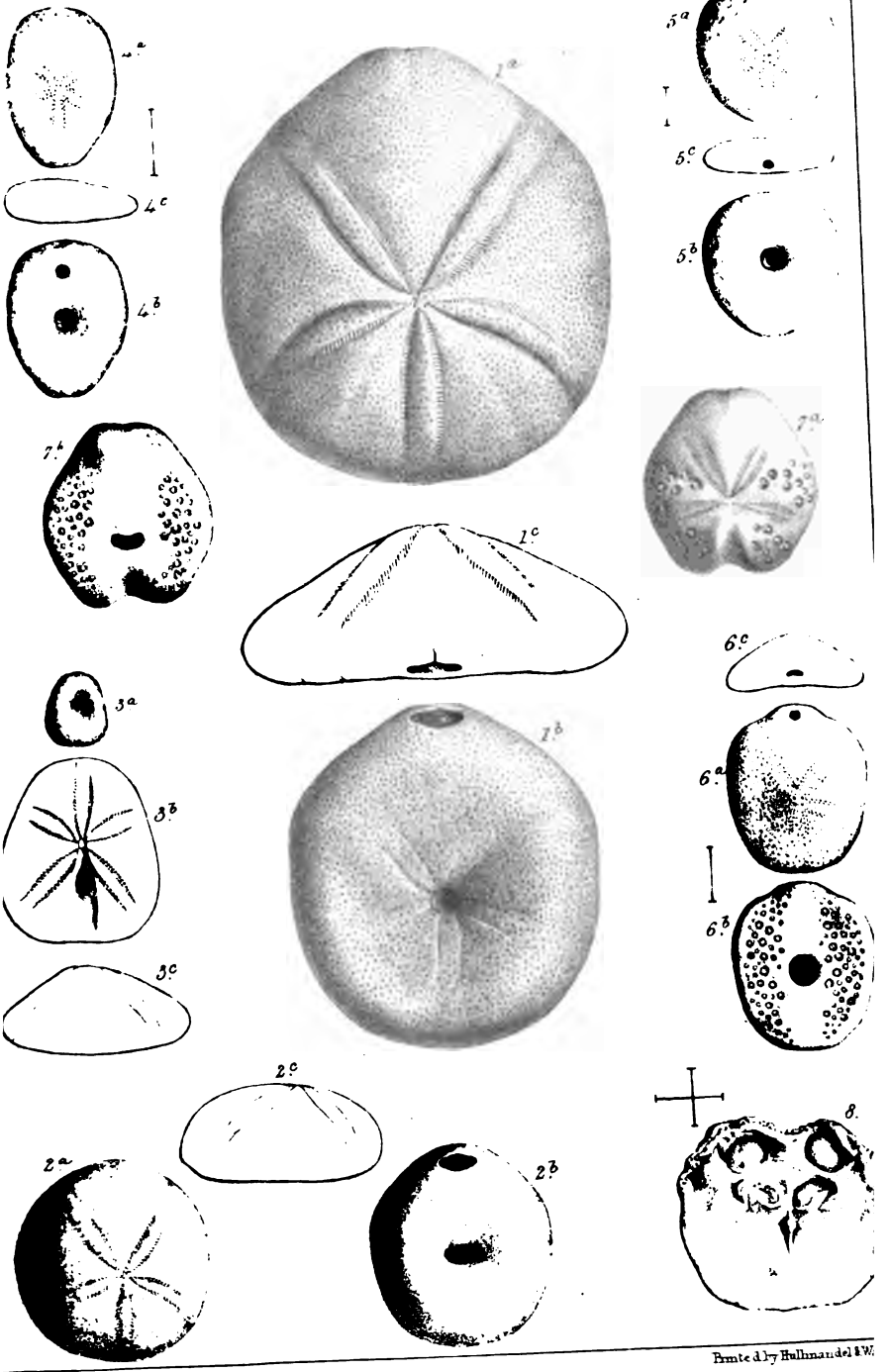

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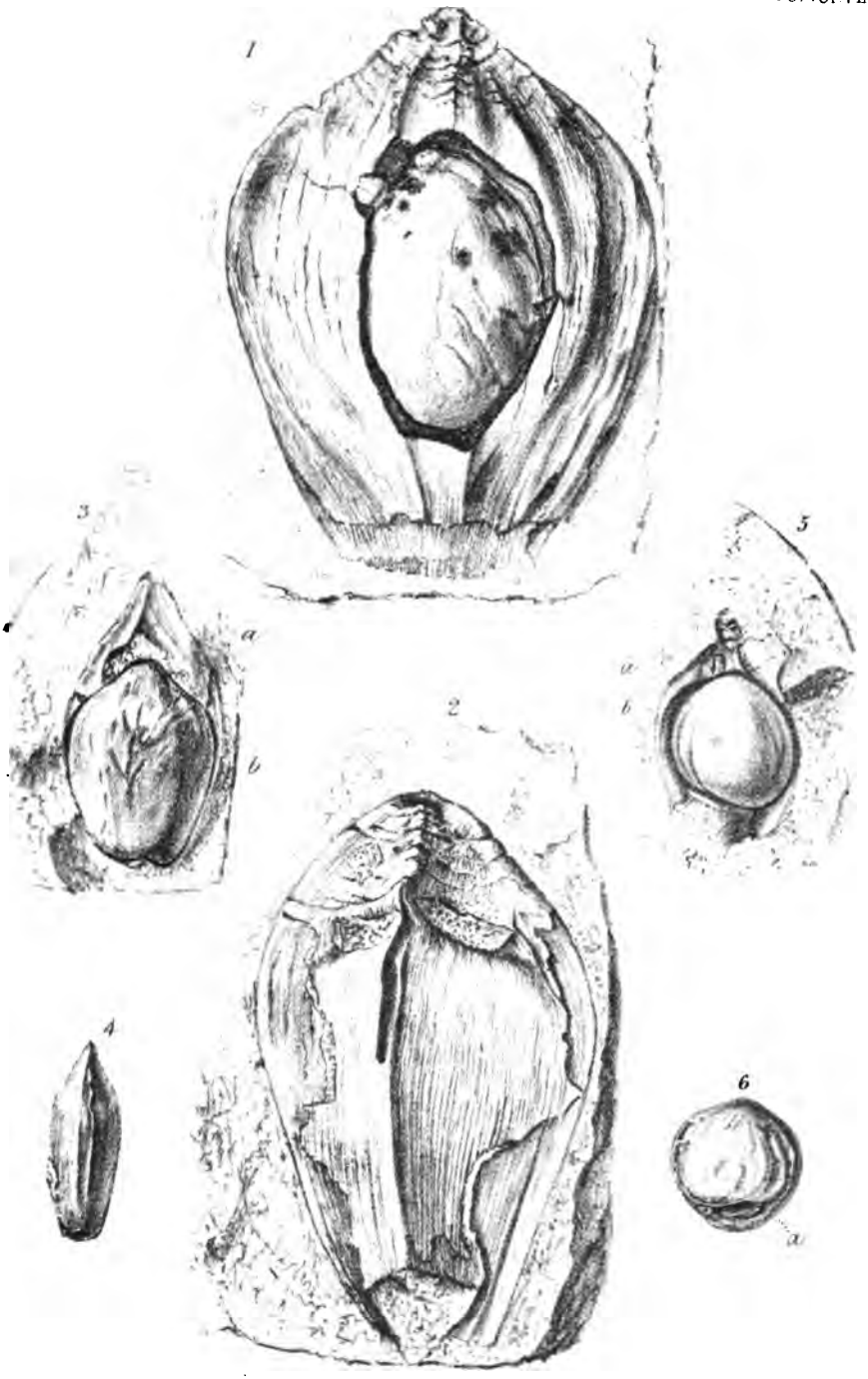
Eocene Fossils of Belgium.



Eocene Fossils of Belgium

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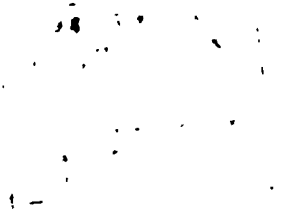

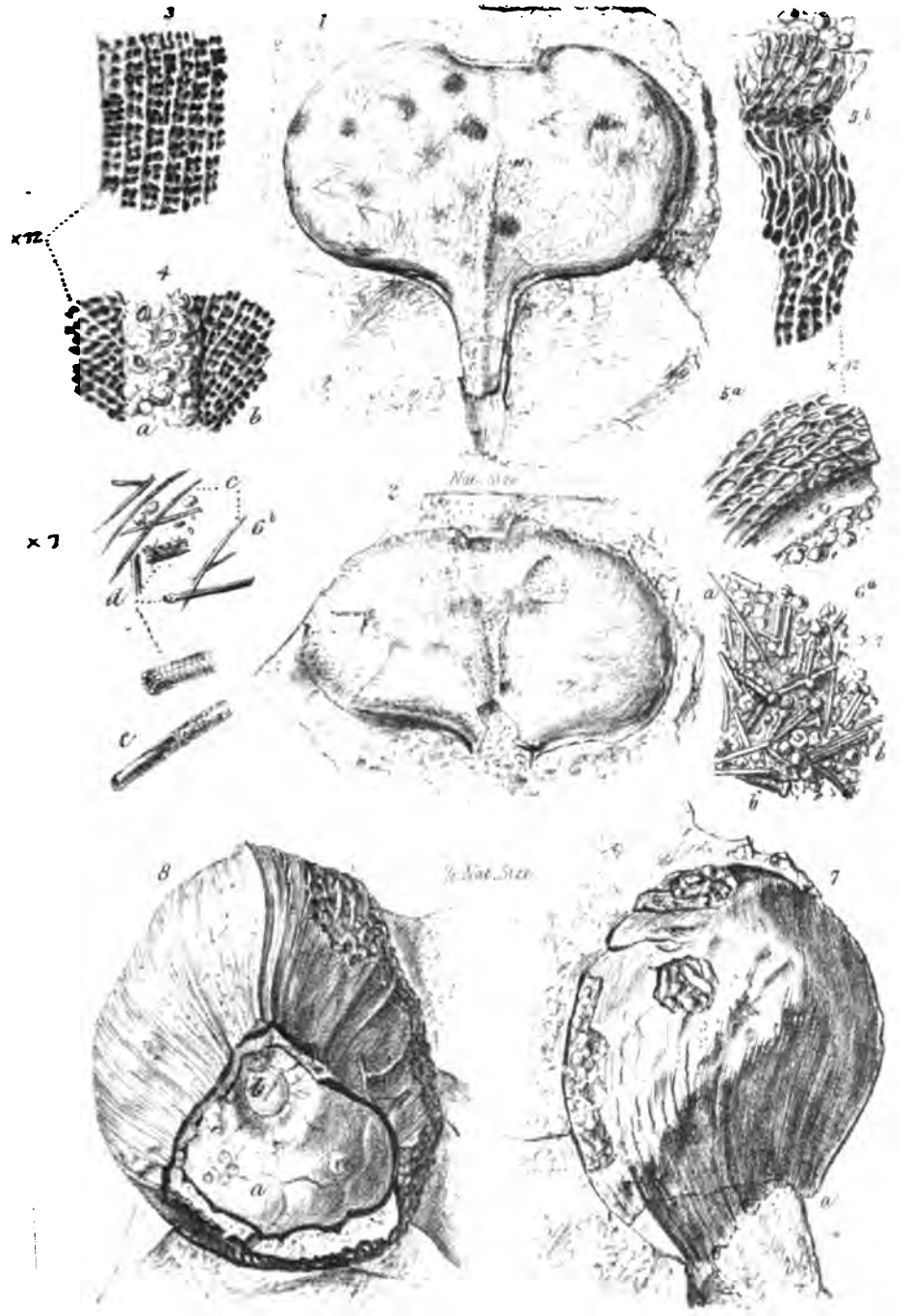

Eocene Fossils of Belgium

(Nonium and Nipadites)

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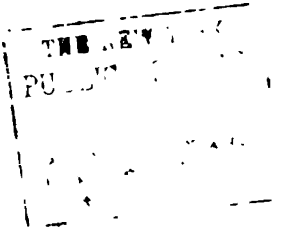
Appendix No. I.

Table of the Classification of the Tertiary Series of Paris, Hampshire, London, and Belgium, in M. Dumont's communication, to the Royal Academy of Belgium, "Sur le Synchronisme des formations tertiaires de la Belgique, de l'Angleterre et du nord de la France," August 2, 1851.*

	BELGIQUE.			BASSIN DE PARIS.	BASSIN DU HAMPSHIRE.	BASSIN DE LONDRES.
2me série (pliocène)	Système scaldisien ..			Crag du Cotentin ? ..	.....	Crag.
	Système diestien					
1re série. Miocène.....	Système bolderien ..	Nymphéen (lignite du Rhin).				
		Marin.....		Falun de Touraine?		
Eocène supérieur ou miocène inf.	Système rupelien	Argile schistoïde de Boom.....		Dépôt lacustre supérieur.		
		Sable jaunâtre		Sable de Fontainebleau.		
Eocène supérieur....	Système tongrien....	Argile verte de Henis		Couche à *Cyrena semistriata*, etc.		
		Sable glauconifère de Lethen		Dépôt lacustre moyen.	Dépôt lacustre de l'île de Wight.	
	Système laekenien ..	Sable sans fossiles		Sable moyen.....	Sable sans fossiles d'Hordwell.	
		Sable fossilifère de Laeken		Couche à *Nummulina variolaria* de Cassel.	Argile de Barton †.	
Eocène moyen	Système bruxellien ..	Sable quarseux.....		Calcaire grossier	Sable de Bracklesham.	Sable de Bagshot.
		Sable calcareux				
		Sable glauconifère				
	Système panisellien ..	Argilo-sableux.				
	Système ypresien	Sable		Partie des sables inférieurs.	Argile de Bognor....	Argile de Londres.
		Argile.....				
Eocène inférieur	Système landenien ..	Nymphéen.....		Lignite soissonnais ..	Plastic clay	Plastic clay.
		Marin.....		Glauconie inférieure.		
	Système hesbayen	(Crétacé).				

* Bulletin Acad. Roy. de la Belgique, tom. xviii. no. 8.

† En admettant, avec M. Prestwich, que le sable de Bracklesham correspond au calcaire grossier, et, par conséquent, au système bruxellien, l'argile de Barton correspondra à la partie fossilifère inférieure de mon système laekenien, dont il paraît, d'ailleurs, renfermer plusieurs espèces fossiles (*Corbula pisum*, *Venus Solandri*, *Cypricardia pectinifera*, *Pecten corneus*, *Turritella brevis*, *Bulla constricta*, *Bulla Sowerbyi*).



PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPER.

On the Superficial Accumulations *and* Surface-markings *of* North Wales. By Prof. A. C. Ramsay, F.R.S., G.S.

Read March 26, 1851.

[For the other Communications read at this Evening Meeting, see vol. vii. p. 200.]

During several summers, while investigating the more solid geology of North Wales in connexion with the Geological Survey of Great Britain, my attention has been occasionally directed to the subject of the action of ancient glaciers in that country, which were first described by Dr. Buckland in 1841*; and I have especially endeavoured to discover traces of a sequence of events characterizing the glacial epoch.

On both sides of the Menai Straits, the low ground of Anglesea and Caernarvonshire is often covered by a coating of "drift†," composed of beds of sand, gravel, and occasionally of clay, mingled with boulders, and sometimes bearing marine shells characteristic of the period.

On Moel Tryfan Mr. Trimmer discovered such shells in beds of gravel, at the height of 1392 feet above the level of the sea‡. From Moel Tryfan, these superficial deposits are continuous, at similar elevations, on the high grounds towards the valley of the Seiont, on the seaward side of the mountain ranges of Caernarvonshire. The valley of the Seiont is comparatively clear of "drift." Between Cwm Seiont

* Proc. Geol. Soc. vol. iii. p. 579 *et seq.* See also Quart. Journ. Geol. Soc. vol. i. p. 153 *et seq.*, p. 300, and p. 460 *et seq.*

† In this paper the term "drift" is used to denote the marine deposits of the Pleistocene sea, without special reference to the transport of materials from a distance.

‡ Proc. Geol. Soc. vol. i. p. 331.

and Llyn Padarn there is a wild moorland tract, covered by the same deposits, in which I found fragments of shells at an elevation of about 1000 feet. On the rough slopes on either side of the lakes of Lanberis, the "drift" has again in a great measure been removed, small patches alone remaining nestled amid the smaller hollows of the hills. Surrounding these more fertile spots, the ruined surfaces of masses of rock rounded and polished by glacier-action often rise almost destitute of vegetation. Between Llanberis and Nant Francon there is another broad high moor formed by "drift" of great thickness, and which, from an average height of about 1100 to 1300 feet, stretches eastward into the valley of Marchlyn-mawr, where it attains an elevation of about 2000 feet. Standing on this moor, above the left bank of the Ogwen, the eye easily detects on the opposite banks a corresponding accumulation, stretching smoothly up the higher valleys towards Aber, and bending on the east and south-east towards the sources of Afon Berthan, the Llafar, and Afon Gaseg; streams rising in the higher recesses of Carnedd Dafyd and Carnedd Llewelyn, on their seaward flanks. I am informed by Mr. Trimmer that he has good reason to believe that this part of these deposits contains shells at a height of about 1000 or 1200 feet. In the valleys, through which flow the streams last named, the "drift" attains an elevation of about 2300 feet, stretching into their wide recesses with a smooth outline, broken only by long lines of faintly-marked terraces, indicative of sea-margins during pauses in the later upheavals of the country. From this highest point it may be followed without a break to the present sea-level. Having ascertained by this unbroken continuity that the drift actually attains an elevation of 2300 feet on the flanks of Carnedd Llewelyn and Carnedd Dafyd, there is no difficulty in understanding the reason of the existence of similar masses in neighbouring isolated valleys high amid the mountains. This occurs in the elevated valley between Y Glyder fawr and Y Garn, in which a deposit of "drift" (see fig. 1, p. 375) stretches from the summit of the cliffs that overhang Cwm Idwal (2300 feet high), to the top of the hills overlooking the Pass of Llanberis.

In Anglesea, although by no means scarce, the larger boulders are much less numerous than in the "drift," where it approaches the mountains of Caernarvonshire. As far as I could discover, they are principally composed of fragments of the rocks of the island. On the opposite shores, approaching the mountains, they gradually increase in quantity, being scattered in and on the "drift," until at its margin, where it surrounds the higher points of land, the boulders often form a large proportion of its material, packed closely together along the sides of the hills, and in the nooks of the higher valleys. Even these coarse accumulations, however, when viewed at a little distance, present a generally smooth and regular outline. Sometimes on isolated hills, or on the summits and sides of high ridges, where the smaller "drift" has been removed by denudation, boulders and subangular masses lie singly scattered on the surface. A good example occurs on the east side of Nant Francon, on the long ridge of Pen-yr-olen-wen. One of these masses lies on the summit of this ridge, about 2000 feet above

the sea. Its dimensions are 9 yards by 5, by 2 yards in height. Its weight cannot be less than from 90 to 100 tons. The parent rock, of felspar-porphyry, is at least a mile distant.

I am well aware that heretofore it has not been customary to consider accumulations at so great an elevation as belonging to glacial marine deposits. They have either been altogether disregarded, or confounded with glacier-moraines. But when we consider their continuity with the shell-bearing strata, their regular smoothly sloping outline, and their gradual change from gravelly drift with a few scattered boulders on the coast, to the coarser and more massive accumulations among the mountains; and further, if we add to this the travelled boulders and masses of rock on the *summits of hills and ridges* 2300 *feet high*, it seems to me impossible to resist the conclusion, that the whole material from the present sea-margin upwards is of marine origin, and due to the operation of one general set of causes extending over a definite period.

In this communication I will not enter on the general proofs of the ancient extension of glaciers among these mountains, formerly so beautifully inferred by Dr. Buckland*. From numerous observations I have convinced myself, on what I consider perfect evidence, that this inference is correct, and with the materials I have collected I may at some future period produce a map of the extent and course of the glaciers of Caernarvonshire, or of North Wales generally. Believing then in their former existence, it is sufficient for my present argument to state that belief.

The "drift" deposits, above mentioned, often rest on and sometimes conceal the rounded, polished, grooved, and scratched surfaces (*roches moutonées*), due to the operation of glaciers, the effects of which are so clearly traceable in the Pass of Llanberis, Nant Francon, and other valleys of Caernarvonshire. *Roches moutonées*, surrounded by, and partly denuded of drift, may be seen near Llyn-y-Gader, in the neighbourhood of the Caernarvon and Beddgelert road, and in the valley leading from the base of Snowdon to Capel Curig. These great glaciers, therefore, *preceded* the deposition of the "drift,"—a circumstance mentioned by Dr. Buckland, in 1841†, who however attributes its distribution "to a great diluvial wave or marine current, advancing from the north, and propelling before it the materials of which the drift is composed‡." It may be objected that denudations during the submergence of the country must have removed the glacier-markings. On the other hand it may be replied, 1st, that the exposed polished rocks are for the most part of extreme hardness; 2nd, that rocks rounded and polished by glaciers, in offering surfaces of small resistance to the sea-waves, run a high chance of escaping their wasting influence during submergence; and 3rd, that they principally occur in the recesses of valleys that anciently, at various levels, formed narrow sinuous arms of the sea, where on the whole still water would prevail. The superincumbent drift has in a great measure preserved them from the wasting effects of atmospheric influences in more recent times.

* *Loc. cit.* † Geol. Proc. vol. iii. p. 579. ‡ *Loc. cit.* p. 584.

It is evident that before this glacier period the land had already received its present grand contour, and this conclusion may be generally applied to European and American surfaces on a large scale underlying the "drift." If the data previously stated be correct, it appears that, after the great glacier period, much of the country was depressed beneath its present level, at least 2300 feet, by which means the glacier-markings were covered by accumulations of superficial detritus. The higher parts of Wales, at the utmost from 800 to 1000 feet above water, must have formed a group of islands, perhaps too insignificant and low to admit of the formation of glaciers on their flanks.

The scratches and polished surfaces in Anglesea (like those in the vale of the Firth of Forth and in the lowlands of Ireland) seem to me to be due to the action of floating ice, the direction of the grooves being quite unconnected with those of the glaciers in the neighbouring mountains of Caernarvonshire. In Anglesea the grooves (at Harlech, in Tywyn-trewan, near the Holyhead Railway, on the "Yellow Sandstone," near Penrhos Llugwy, on the coast near Carmels Point, and at various localities near Llanfairynghornwy) generally run about E. 30° N. It is worthy of remark that near Penrhos-Llugwy, on the polished and grooved surfaces, potholes occur (where no stream could have run) of the kind frequently made on sea-coasts by the gyration of stones in hollows, showing that, since the rocks were smoothed and scratched, they have formed a sea-margin, from which the drift has been removed by denudation.

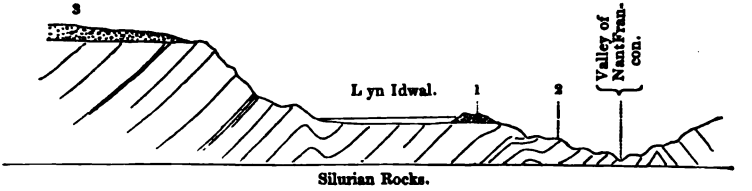
Whatever the conditions were under which boulders were dispersed from the height of 2300 feet downwards, they were brought to a close by the gradual re-elevation of the country. One of the characteristic features of the scenery of North Wales is, as I have elsewhere observed*, due to this elevation, the outlets of certain valleys being dammed up by greater accumulations of sediment towards their openings, the free egress of the drainage being prevented, and lakes having been formed, after the manner indicated by Mr. Darwin in his "Geological Observations on South America†." Examples of this may be seen at low levels in Caernarvonshire in Llyn Cwellyn and Llyniau, and on high ground in some of the lakes on the north side of Cader Idris in Merionethshire, and in Marchlyn-bach and Marchlyn-mawr in Caernarvonshire, where, in the latter case, the barrier of "drift" reaches an elevation of about 2000 feet.

But there are other lakes, such as Llyn Llydaw, on the Capel Curig side of Snowdon, and the celebrated Llyn Idwal, which are clearly dammed up, not by marine deposits, but by the moraines of glaciers (see fig. 1). As an example of the moraine-dammed lakes I select Llyn Idwal, in Cwm Idwal, the moraines of which have been described by Mr. Darwin‡. A terminal moraine spreads across the valley, and dams up the lake. Lateral moraines extend up the sides of the valley on either side.

* Athenæum (No. 1171), 1850, p. 377. † P. 24.

‡ Lond., Edinb. and Dubl. Phil. Mag. 1842, vol. xxi. p. 180; and Edinb. N. Phil. Journ. 1842, vol. xxxiii. p. 352.

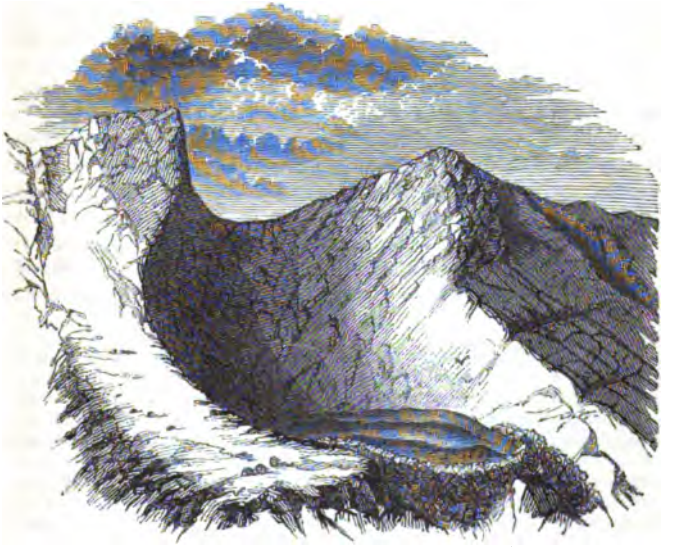
Fig. 1.—*Diagram illustrative of the damming up of lakes by means of moraines, as in the case of Llyn Idwal, and of the relation of the Drift to the subsequent Glacier-conditions.*



1. Moraine forming the dam of the lake.
2. Grooved and polished surfaces formed by more ancient glaciers.
3. Pleistocene "drift" at an elevation of 2300 feet.

There are other cases, as in Cwm Graianog, Nant Francon (see fig. 2), where, the drainage immediately percolating the loose piles of stones, no pent-up water is found within the barrier.

Fig. 2.—*Cwm Graianog, Nant Francon, having a terminal moraine of loose stones which admits of the drainage of the valley.*



But these moraines are often at a lower level than much of the Pleistocene "drift," as in the case of Llyn Idwal, where the level of the lake is about 1000 feet beneath the level of the ordinary "drift" on the summit of the cliffs, which I have already stated is in a high isolated valley, open at both ends (see p. 372). It is without tributary valleys, and the small rivulet which gradually gathers in its hollow, and flows into the Pass of Llanberis, has rarely succeeded in cutting through the drift of the higher ground to the solid rock beneath. It is im-

portant here to recall the circumstance that the "drift" of this valley attains an elevation about equal to that of similar deposits, which may be traced without a break from the seaward flanks of Carnedd Llewelyn to the shores of the Menai.

If, therefore, the loose moraine-heaps of Cwm Idwal had been formed during the great glacier period already mentioned, it would either in all probability have been destroyed during the depression and re-elevation of the land that followed that period, or it would have been covered over and smothered in the succeeding drift.

I am therefore forced to the conclusion, that there were two glacier periods in this land; first, one preceding our Pleistocene deposits, and a second on a much smaller scale, either when the land was rising from the Pleistocene sea, or possibly when during a portion of this process of rising it attained a higher elevation than at present. The moraines of these latter glaciers are to be seen in the mouths and recesses of the higher valleys, such as Cwm Idwal and Cwm Graianog, and in the valley of Llyn Llydaw and Cwm-y-Clogwyn, on the flanks of Snowdon, and also in the upper part of Cwm-llafar, where a small lake has been drained by the stream cutting its way to the base of the moraine*. These moraines are often of a massive character, being composed of piles of heavy angular stones heaped rudely together. In Cwm Graianog, on the summit of the pile of smaller blocks, half way between the bounding hills, there is a stone, now split by the weather, measuring $33 \times 27 \times 4\frac{1}{2}$ feet, and weighing about 250 tons. The shortness of the courses of these glaciers at first seemed to me a great difficulty, varying as some of them do from $\frac{3}{4}$ of a mile to $1\frac{1}{4}$ mile in length. An examination of the maps of MM. Schlagintweit† removed this objection, for on ground of similar form glaciers equally short are not uncommon. In Wales true moraines never occur in the main valleys opening into low tracts approaching the sea. In many of these valleys even most of the drift has been removed, by means which at a future period I hope to explain.

* The glacier has originally extended beyond this point, having in its course scooped out *a long straight hollow in the drift*. That this was not hollowed out by the stream is evident from the circumstance that the surface of *alluvial* detritus is not thickly strewed with boulders accumulated by the gradual removal of intermingled smaller sediment by means of river-action. The broad terrace of drift on the right bank of the stream is thoroughly charged with such boulders, often of large size. The removal of the lighter material by river-action would have concentrated these on the surface of the straight alluvial hollow through which the stream flows. This *concentration* of boulders may be seen in many of the Caernarvonshire valleys. A well-marked instance occurs on the banks of the river Gorfai, two miles S. and S.E. of Caernarvon.

† Untersuchungen über die phys. Geogr. der Alpen, 8vo. 1850.

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY,

January 1st, 1852, to March 31st, 1852.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

ALNWICK Scientific and Mechanical Institution, 27th Report. *G. Tate, Esq., F.G.S.*

American Journal of Science and Arts. Vol. xiii. nos. 37, 38. *Prof. Silliman.*

Athenæum Journal for December 1851, January, February, 1852.

Berlin, Geological Society of, Journal. Vol. iii. part 3.

Chemical Society, Quarterly Journal. No. 16.

France, Société Géologique de, Bulletin. Deux. Série, tome ix. f. 1–4.

Horticultural Society, Journal. Vol. vii. part 1.

Institute of Actuaries of Great Britain, Constitution and Laws.

——— The Assurance Magazine. No. 6.

Jahrbücher des Vereins für Naturkunde im Hezogthum Nassau. 7 Heft. 1, 2, 3 Abtheil. *The Society of Nat. Hist. of Wiesbaden.*

Journal of the Indian Archipelago. Vol. v. no. 10. *J. R. Logan, Esq., F.G.S.*

London, Edinburgh, and Dublin Philosophical Magazine, for January, February, and March. *R. Taylor, Esq., F.G.S.*

Manchester, Literary and Philosophical Society of, Memoirs. Second Series, vol. ix.

Moscou, Société Impériale des Naturalistes. Nouveaux Mémoires, vol. ix.

——— Bulletin, Année 1851. No. 2.

North British Review, No. 32, February 1852.

Nuovi Annali delle Scienze naturali e Rendiconto dei Lavori dell' Accademia delle Scienze dell' Instituto di Bologna. Ser. 3. vol. ii. iii. and iv., July and August.

Paris, Academy of Sciences of. Comptes Rendus, Deux. Sem. tom. xxxiii.; tome xxxiv. nos. 1–7.

Royal Agricultural Society of England, Journal. Vol. xii. part 2.

Royal Asiatic Society, Journal. Vol. xiii. part 1, and vol. xiv. part 1.

Royal Astronomical Society, Memoirs. Vol. xx.

——— Monthly Notices. Vol. xi.

Royal Institution of Cornwall, 32nd Annual Report.

Royal Society, Proceedings. Vol. vi. nos. 82–85.

Sheffield Literary Philosophical Society, 29th Annual Report of the. *H. C. Sorby, Esq., F.G.S.*

Vienna, Imperial Academy of, Transactions. Vol. ii. part 3.

——— Bulletin, 1851. Vol. vi. parts 1–5, and vol. vii. parts 1, 2.

II. GEOLOGICAL AND MISCELLANEOUS BOOKS.

Names of Donors in Italics.

Allgemeines Reportium der Min. Geog. Geol. in Petref. 1840–49. *T. R. Jones, Esq., F.G.S.*

Ansted, D. T. On the Absorbent Power of Chalk.

Athenæum Club, Rules and List. 1851.

Beardmore, Nathaniel. Hydraulic Tables.

Beke, Dr. C. T. An Enquiry into M. Antoine d'Abbadie's Journey to Kaffa.

———. A Summary of Recent Nilotic Discovery.

———. On the Alluvia of Babylonia and Chaldea.

Bosquet, J. Description des Entomostracés fossiles des Terrains tertiaires de la France et de la Belgique.

Catalogue of the London Library, vol. ii. *Committee of the London Library.*

Charlesworth, E. Catalogue of British Marine Recent Shells.

Correspondence relative to the recent Discovery of Gold in Australia. *Sir P. G. Egerton, Bart., M.P., F.G.S.*

D'Archiac, A. Histoire des Progrès de la Géologie de 1834 à 1850. Vol. iv.

Darwin, C. Monograph on the Subclass Cirripedia.

Debey, Dr. M. H. Uebersicht der urweltlichen Pflanzen des Kreide gebirges überhaupt, und der Aachener Kreide-schichten insbesondere. *Sir R. I. Murchison, F.G.S.*

———. Entwurf zu einer geognostisch-geogenetischen Darstellung der Gegend von Aachen. *Sir R. I. Murchison, F.G.S.*

De Koninck, Dr. L. Description des Animaux fossiles qui se trouvent dans le Terrain Carbonifère de Belgique. Supplément.

———. Nouvelle Notice sur les Fossiles du Spitzberg.

———. Discours sur les Progrès de la Paléontologie en Belgique.

Des Moulins, C. Études sur les Échinides, 1^me^ partie. *S. P. Pratt, Esq., F.G.S.*

D'Orbigny, A. Prodrome de Paléontologie stratigraphique universelle. Vol. ii.

———. Cours élémentaire de Paléontologie et de Géologie. Vol. ii. fasc. 1, and Tables.

Leonhard, G. Die Quartz-führende Porphyre. *T. R. Jones, Esq., F.G.S.*

Faraday, Dr. M. Experimental Researches in Electricity.—On the Lines of Magnetic Force.

Forchhammer, G. Hans Christian Örsted. Mindeskrift.

Great Britain Coasting Pilot, by Capt. G. Collins, 1723. *T. R. Jones, Esq., F.G.S.*

Introductory Lectures delivered at the opening of New College, London. *The Principal of New College.*

Lea, Isaac. On the genus Acostæa of D'Orbigny, a freshwater Lamellibranchiate.

———, and *H. C. Lea.* Description of a new genus of the family Melaniana, and of many new species of the genus Melania.

———. Descriptions of five new species of Anodontæ.

Leymerie, A. Mémoire sur un nouveau type Pyrénéen parallèle à la Craie proprement dite.

Lyell, Sir C. A Manual of Elementary Geology. 4th Edition.

Mackinnon, W. A. History of Civilization and Public Opinion. 3rd Edition.

Murchison, Sir R. I. On the Silurian Rocks of the South of Scotland.

———. On the Slaty Rocks of the Sichon.

———. On the Earlier Volcanic Rocks of the Papal States.

———. On the Vents of Hot Vapour in Tuscany.

———. On the Distribution of the Flint Drift of the South-East of England.

Ramsay, Prof. A. C., W. W. Symth, and Dr. Percy. Introductory Lectures to the Courses of Geology, Mineralogy, and Metallurgy.

Reports of Inspectors of Coal-mines to H.M. Secretary of State. *Earl of Enniskillen, F.G.S.*

Reports on the Coal of Hilsborough, New Brunswick. *J. de W. Spurr, Esq.*

Schäffer, Dr. F. R. Die Bimsteinkörner bei Marburg in Hessen und deren Abstammung aus Vulkanen der Eifel.

Scharenberg, Dr. W. Ueber Graptolithen, mit besonderer Berücksichtigung der bei Christiania vorkommenden Arten.

Strickland, H. E. On Geology in Relation to the Studies of the University of Oxford.

Von Buch, Baron L. Lagerung der Braunkohlen in Europa.

————. Ueber Blattnerven und ihre Vertheilung.

————. Ueber eine Muschel-Umgebung der Nord-see.

White, Walter. Papers on Railway and Electric Communications.

Wyld, James. Notes on the Distribution of Gold throughout the World.

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

June 2, 1852.

W. H. Gomonde, Esq., J. H. Blofeld, Esq., and Dr. Finlay, R.N., were elected Fellows.

The following communications were read:—

1. *On the* Geology *of the* Bahamas, *and on* Coral-formations *generally*. By Capt. R. J. Nelson, R.E.

[Communicated by Sir C. Lyell, V.P.G.S.]

2. *On some* Fossil Plants *from the* Lower Trias *of* Warwickshire. By Dr. G. Lloyd, F.G.S.

[This paper was withdrawn by the Author, with the permission of the Council.]

June 16, 1852.

M. J. Scobie, Esq., was elected a Fellow.

The following communications were read:—

1. *On a protruded mass of* Upper Ludlow Rock *at* Hagley Park *in* Herefordshire. By H. E. Strickland, Esq., F.R.S., F.G.S.

So laboriously minute have been the researches of the Officers of the Geological Survey of Great Britain, that it is only where some

fresh sections have been subsequently exposed by the operations of nature or of man that any material additions or corrections of that Survey can be looked for. A case of the kind has lately occurred in Herefordshire, revealing a small protrusion of Silurian rocks in the midst of the Old Red Sandstone, and accompanied by circumstances of some geological interest.

A quarry having been opened near the base of the Old Red Sandstone, a few hundred yards west of Hagley House, near Lugwardine, and a deep drain having been cut from the quarry towards the S.E., the junction-beds of the Old Red Sandstone and of the Upper Ludlow Rock were unexpectedly exposed. This circumstance attracted the notice of M. J. Scobie, Esq., of Hereford, to whom I am indebted for having my attention drawn to the spot, and for many interesting organic remains and geological details which his residence in the vicinity enabled him to collect. I must also express my obligations, and those of the other geological friends who accompanied me, to Robert Biddulph Phillipps, Esq., the owner of the land, who kindly caused part of the quarry to be re-opened for our inspection.

The area of Silurian rocks here exposed on the surface does not exceed three or four acres; it consists of yellowish sandstones referable to the "Downton Sandstones" of Sir Roderick Murchison, resting on grey micaceous Upper Ludlow schists, and dipping on all sides beneath the sandstones and marls of the Old Red Series. They seem to form a portion of a very flattened dome, and the quarry, which extends about seventy yards from N.W. to S.E., cuts through this dome on its south-western slope. Such at least is the conclusion drawn from the dip of the beds, which at the north end of the quarry is about 10° N.W. by W.; at the middle of the quarry, 5° W.N.W.; about twenty yards further S., 8° W.S.W.; and at the southern extremity, 7° S.S.W. The following section is here exposed in descending order, as far as the irregularities of the stratification permit them to be measured.

		ft.	in.
Old Red Sandstone...	1. Red marls and clays, containing bands of whitish sandstone, not calcareous, about	12	0
Downton Sandstones.	2. Hard brownish sandstone	2	0
	3. Flaggy, slightly micaceous, brown sandstone	2	0
	4. Highly micaceous, thin-bedded, brown sandstone	2	0
	5. Band of clay and rubble, about	0	6
	6. Micaceous yellowish sandstone, with traces of carbonized plants	2	0
	7. Clay and rubble	0	6
	8. Micaceous yellowish sandstone, with numerous fragments of carbonized plants	4	0
Upper Ludlow Rocks.	9. Bones, teeth, and scales of fish, about	0	1
	10. Grey micaceous shale, effervescing with acid, full of fossils, about	4	0
		29	1

The vegetable remains in the beds Nos. 6 and 8 are interesting from their extreme antiquity, but in general present no traces of their organic structure. They are merely rounded and water-worn fragments converted into a coaly mass, which cracks in drying. When

ignited, these fragments burn like anthracite, without smoke or flame, and remain ignited until they are reduced to a light white ash. The occurrence of vegetable remains in the corresponding beds at Downton Castle is noticed by Sir R. Murchison* and near Stoke Edith, and in the May Hill district by Prof. Phillips†.

The bed No. 9 is interesting as being unquestionably the representative of the "Ludlow Bone Bed," described by Sir R. Murchison‡. His description of this deposit near Ludlow, as "a mass of scales, ichthyodorulites, jaws, teeth, and coprolites of fishes, united by a gingerbread-coloured cement," is precisely applicable to the stratum at Hagley. The cement which unites the bones is calcareous and imperfectly crystalline, exhibiting a *chatoyant* lustre when the eye catches the light reflected from the cleavage-planes. This singular deposit of ichthyic remains occurs as a thin band, in some places no thicker than a wafer, and gradually increasing at other points to about an inch and a half in thickness, as if deposited by eddies in shallow depressions of the sea-bottom§. These minute osseous fragments are mostly much water-worn and highly polished by mutual friction. Some of them are black, but the majority are of a yellowish or ferruginous tint. As very few of the bones or teeth are sufficiently perfect to indicate generic or specific characters, we are only able to enumerate the following:—

Spines of *Onchus Murchisoni*, Agass., Sil. Syst. pl. 4. f. 10.
Teeth of *Thelodus parvidens*, Agass., Sil. Syst. pl. 4. f. 34–36.
Teeth resembling that figured in Sil. Syst. pl. 4. f. 37, but serrated at the margin.
Ganoid scales.

The only molluscous remains in the fish-bed are the *Orbicula rugata*, Sil. Syst. pl. 5. f. 11, and an *Orthis*.

In some places fragments of coaly matter, similar to that in the bed No. 8, are mixed up with these osseous remains. One of these carbonaceous pellets seems to be the seed of some terrestrial plant. It is globular, about a quarter of an inch in diameter, and being broken across exhibits a central cavity, the parietes of which are about one-tenth of an inch thick, and composed of fibres radiating to the external surface‖.

The bed No. 10 corresponds in character with the uppermost strata of the Ludlow Rocks wherever they are visible in the neighbourhood. It is a fine-grained sandy shale, of a greenish or greyish colour, abounding with small particles of mica, and effervescing with

* Silurian System, p. 197. † Mem. Geol. Survey, vol. ii. pp. 176, 188, 312.
‡ Sil. Syst. p. 198.
§ Precisely the same conditions exist in the case of the well-known bone-bed at the base of the Lias, and are doubtless due to the difference between the specific gravity of the fish-bones and that of the arenaceous grains of the sea-bottom, causing the former to be separated from the latter by the action of the currents.
‖ I propose on a future occasion to give a fuller description of these singular bodies, which have since been detected in the same stratum at several other localities.

acids, although not sufficiently calcareous to deserve the name of a limestone.

The following organic remains occur in it at Hagley Quarry:—

Cyathophyllum?
Favosites polymorpha, *Goldf.* sp., Sil. Syst. pl. 15. f. 2.
Cophinus dubius, *König*, Sil. Syst. pl. 26. f. 12.
Crinoidal stems (pentagonal).
Cyathocrinites macrostylus, *Phillips*, Mem. Geol. Surv. ii. p. 384.
Serpulites longissimus, *Murch.*, Sil. Syst. pl. 5. f. 1.
Homalonotus Knightii, *König*, Sil. Syst. pl. 7. f. 1, 2.
Calymene Blumenbachii, *Brongn.*, Sil. Syst. pl. 7. f. 5.
Rhynchonella semisulcata, *Dalm.* sp. (*Terebratula lacunosa*, Sil. Syst. pl. 5. f. 19).
—— Wilsoni, *Sow.* sp., Sil. Syst. pl. 6. f. 7 *a*.
—— nucula, *Sow.* sp., Sil. Syst. pl. 5. f. 20.
Orthis orbicularis, *Sow.*, Sil. Syst. pl. 5. f. 16.
—— lunata, *Sow.*, Sil. Syst. pl. 5. f. 15.
Strophomena filosa, *Sow.* sp., Sil. Syst. pl. 13. f. 12.
Leptæna sarcinulata, *Schlott.* sp. (*L. lata*, Sil. Syst. pl. 5. f. 13).
Orbicula striata, *Sow.*, Sil. Syst. pl. 5. f. 12.
—— rugata, *Sow.*, Sil. Syst. pl. 5. f. 11.
Lingula minima, *Sow.*, Sil. Syst. pl. 5. f. 23.
Orthonota amygdalina, *Sow.* sp., Sil. Syst. pl. 5. f. 2.
—— retusa, *Sow.* sp., Sil. Syst. pl. 5. f. 5.
Avicula ampliata, *Phillips*, Mem. Geol. Surv. ii. pl. 23. f. 1.
Orthoceras bullatum, *Sow.*, Sil. Syst. pl. 5. f. 29.
—— perelegans, *Salter*, Mem. Geol. Surv. ii. pl. 13. f. 2.
—— ibex, *Sow.*, Sil. Syst. pl. 5. f. 30.
—— gregarium?, *Sow.*, Sil. Syst. pl. 8. f. 16.

Many of these fossils, especially the *Orthocerata*, are penetrated with sulphuret of iron, which gives them a bright metallic gloss.

In addition to the above-mentioned invertebrate forms, an interesting portion of a crustacean has been forwarded to me by Mr. M. J. Scobie from the Upper Ludlow shale underlying the bone-bed, of which Mr. Salter has kindly undertaken the description. (See p. 386.)

Traces of ichthyic remains, especially the minute teeth of *Thelodus parvidens*, are occasionally found interspersed in the bed No. 10, but never in the same abundance as in No. 9.

Having now enumerated the strata of Hagley quarry and their organic contents, I must make a few remarks on the geological phænomena attending them.

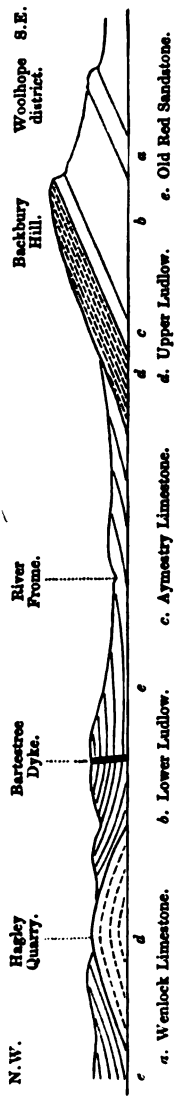
It was stated above that the beds here exposed assume the form of a flattened dome. By reference to the map it will be seen that this protruded dome is about half a mile to the N.W. of the well-known dyke of greenstone at Bartestree, which cuts through horizontal strata of Old Red Sandstone, and runs in an E.N.E. direction towards the S. edge of the protruded Silurian mass of Shucknall Hill*. About

* See Murchison, Sil. Syst. p. 185; and Phillips, Mem. Geol. Surv. vol. ii. p. 180.

a mile and a half further to the S.E., we come to the elevated region of Woolhope, the axis of which runs for more than ten miles still in a S.E. direction. It appears, therefore, that the ejection of the trap-dyke at Bartestree, together with this protrusion of Silurian rocks at Hagley Park, occur exactly on the axial line of the great elevation of Woolhope.

But though this coincidence of position deserves notice, yet the forces which have caused these minor protrusions have in fact acted nearly at right angles to the direction indicated. The Woolhope region, though possessing an axis from N.W. to S.E., is essentially an *area*, and not a *line*, of elevation. Its pressures have been distributed, not in two opposite directions from an axis, but in every direction from a centre. In conformity with this view we find that in its north-western portion it is cut through by the "great Mordiford fault," running N.E. by E. (or nearly at right angles to the major axis), and causing the strata about Dormington and Stoke Edith to assume the same strike. Beyond the Woolhope area we find the valley of the River Frome, the Bartestree Dyke, and the protruded Silurian mass of Shucknall Hill assuming almost exactly the same east-north-easterly direction. And in the small dome-like protrusion of Hagley Park, which lies parallel to Bartestree Dyke, and precisely in the axis of Shucknall Hill, we find a further proof of the same movement.

Section from Hagley Park to the Woolhope District.



It appears probable, then, that the pressure caused by the elevation of the central dome of the Woolhope area, acting in every direction, has on the north-west side caused great undulations in the Silurian and Devonian strata which lie beyond the region of actual elevation. In two instances, that of Shucknall Hill and of Hagley Park, the denudation of the Old Red Sandstone has exposed to view the subjacent Silurian rocks on the summits of these undulations. Great shattering and dislocation would of course accompany these movements, and in the Bartestree Dyke it is interesting to find one of the great crevices thus formed, and filled with eruptive matter derived from the Plutonic region where all these great movements originated.

The accompanying section will serve to show the relations in which the Hagley protrusion stands to the Bartestree dyke and the Woolhope elevation.

2. *Description of the* Pterygotus problematicus, *Agass.* By J. W. Salter, Esq., F.G.S.

[Plate XXI.]

The limbs of this interesting Silurian fossil not having been hitherto discovered, the present specimen is of considerable interest, as connecting it satisfactorily with the species so fully figured by Agassiz, which was obtained from the basement-beds of the Old Red Sandstone of Forfarshire*. But, though of the same genus with the Scotch fossil, it presents characters which separate it specifically.

As there are on the same slab with it numerous specimens of *Avicula retroflexa*, Hisinger, with *Orthis lunata* and *Orbicula rugata*, there can be no doubt of its being in the Upper Ludlow rock; and we are therefore justified in considering it as belonging to the species which is so common (always in a fragmentary state) in the same stratum throughout Shropshire, Herefordshire, and the Malverns; and a fragment of the carapace of which is figured by Agassiz, Sil. Syst. pl. 4. f. 4, 5.

Of the two fragments on the slab, the best preserved is that of a finger (probably the fixed one), Pl. XXI. fig. 1. It is 2¼ inches long and 7½ lines broad, exclusive of the spines, and of equal breadth throughout; but it neither shows the base nor the tip, and must have been considerably longer. The substance is very thin, sections of the broken ends showing this condition very plainly.

The spines along the inner edge are long, conical, or almost cylindrical, and are set fully their own breadth apart: they are of various sizes, several small ones being interposed between the larger spines. There are seventeen of the smaller spines on the fragment, each about a line high; there are two larger ones about ¼ inch in length, and one large spine towards the middle, which is broken, but its base is ¼ inch broad. All the spines turn a little backward (as in *P. anglicus*, Ag.) and are finely striated lengthwise, rather obliquely. The surface of the finger itself is very ill preserved and crushed; it appears not to have been quite smooth, and there are scattered small tubercles toward the inner edge, as well as minute prickles interspersed between the spines.

In *P. anglicus*, as figured by Agassiz, the spines are much larger and more coarsely striate, and they stand so close together that their bases often touch; they are, too, fewer in number than in our fossil, and the finger is shorter than this appears to have been.

The other fragment, fig. 2, is more doubtful; it has spines along its margin like the last, but they are much larger (about 4 lines long), and more closely placed, so that their bases approach each other. There are also small prickles interspersed as in the last. But the margin on which they are set, instead of being slightly concave, is considerably convex, and, unless it has been much curved by pressure, could hardly have belonged to the extremity of the limb. On this fragment, but probably not connected with it, there is a large conical spine or articulation, constricted at its base; it is an inch long by

* Poiss. Foss. du Vieux Grès Rouge, p. xix. note, and pl. A.

5 lines broad, and has one of its edges closely serrated. It is of the same thin substance as the other fragments, and is striated longitudinally, like the other spines, the striæ radiating upwards from its base. It is perhaps the terminal joint of one of the feet, or, if articulated with the fragment to which it is attached, it might indicate one of the lateral appendages such as are found in the abdomen of *Limulus*, and the convex spiny border might then well be part of the abdomen itself. This, I am inclined to think, is the right explanation.

In the collection of the Geological Survey there are fragments of the limbs of this Crustacean, found in the 'Tilestones' at the base of the Old Red Sandstone at Kington, Presteign. Two or three joints, each about an inch long, and the broadest more than half an inch in width, are found together; they are compressed toward their inner edges, and thickened on the back or outer edge, which is also marked by several of the semicircular folds so characteristic of the entire crust. With these is associated a large fragment like the tail-flap of a lobster (but much more probably the base of one of the thoracic feet), of which a fragment measures 2½ inches; it is very thick on one side, and towards its outer margin is covered by closely set tubercles, which become small spines on the edge itself. The thick portion is smooth externally, or has only a few of the characteristic folds; and the outer edge shows no trace of the large crowded spines or appendages so conspicuous in this portion of the *P. anglicus*.

It is probable that there are numerous species of the genus in the old rocks. Fragments with the characteristic markings occur in Upper Silurian strata at Gaspé, Lower Canada; and portions of the limbs of a Bohemian species have been figured by the late M. Corda as the feet of *Brontes* *, a genus of Trilobites.

Naturalists seem to be agreed that the *Pterygotus* was a gigantic Entomostracan, and Agassiz published it as such, in the explanatory note to his figures. It differed from *Limulus* in having the segments of the abdomen freely articulating with each other †, in this respect agreeing with *Eurypterus*, a genus of equally gigantic Crustaceans, which Prof. M'Coy, I think very happily, arranges in the *Pœcilopoda*. He has examined perfect Scotch specimens of *Pterygotus*, and tells me that "the eye-like pits on the shield are very like those of *Eurypterus*, but they are as large as the orbits of a horse's eye." I hope he may be induced to present his notes on this genus and his drawings to the Society.

* Prodr. Trilob. Sil. Syst. Bohème, pl. 4. f. 33.

† It may be worth while here to remark, as there seems to be a misconception about it on the part of some foreign naturalists, that the *Limuli* of the Coal-formation (*Bellinurus*, König) differ in nothing from the true *Limuli* except in the points of the anchylosed abdominal segments being more produced; they are by no means separate or movable, as numerous specimens show. The eyes too, though not well shown in Mr. Prestwich's figures (Trans. Geol. Soc. 2 Ser. vol. v. pl. 41), are in the usual position in all the species.

EXPLANATION OF THE FIGURES.

PTERYGOTUS PROBLEMATICUS.

Pl. XXI.

Fig. 1 *a*. Part of the claw of *Pterygotus problematicus*, Agass., from the Upper Ludlow Rock of Hagley Park, Herefordshire:—this is probably the fixed finger, and shows the striated spines of unequal size.

Fig. 1 *b*. Some of the spines, magnified.

Fig. 2 *a*. From the same slab:—a portion probably of the spinous edge of the abdomen, with one of the lateral appendages (*) attached.

Fig. 2 *b*. The appendage, fig. 2 *a**, magnified, to show the radiating striæ and lateral teeth. This large spine or appendage may possibly be a terminal joint of one of the feet, pressed against the fragment, fig. 2 *a*, but not articulated with it.

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3. *Description of some* GRAPTOLITES *from the* SOUTH *of* SCOTLAND. By J. W. SALTER, Esq., F.G.S.

MR. HARKNESS has been so good as to send me specimens of many Graptolites he has collected, and information respecting several of the localities mentioned in his paper, on the Silurian Rocks of the South of Scotland, which appears in this Number of the Journal.

He has added one very interesting species to the British list, by finding the *Diplograpsus teretiusculus*, Hisinger, a species characteristic of the alum slates of Sweden, at Glenkiln, Dumfriesshire. He has also found *D. ramosus*, Hall, at Hartfell in the same district: this previously was only known in Wigtonshire.

Numerous specimens collected by him of the *Rastrites triangulatus*, Harkness, prove it, as Prof. M'Coy had surmised, to be only the younger portion of *Grapt. Sedgwickii*, Portlock. A large series too of *G. incisus*, Harkness, enables us to refer that species to *G. sagittarius* of Hisinger, of which there are good specimens in the Society's Museum, and which has been lately well-figured by Geinitz†. A figure of its young and full-grown stages are given, Pl. XXI. fig. 8.

Mr. Harkness also permits me to correct an error into which he was led in his previous memoir‡. The strata of South Kirkcudbrightshire have been hitherto referred to the age of the Wenlock shale, but the species of Graptolites quoted by Mr. Harkness from that locality, would invalidate this reference; viz. *Graptolites* (*Diplograpsus*) *foliaceus*, Murch., *G. tænia*, Salter, and *G. ludensis*, Murch.

With regard to the first species, the evidence when examined turns out to be quite inconclusive, and there is, as yet, no instance in Britain of a double-graptolite being found above the Caradoc sandstone.

G. tænia of his list proves to be an indeterminable fragment, and the species itself, founded as it was on an imperfect specimen, must be cancelled§. Geinitz has already referred it to *G. sagittarius*.

† Verstein. Grauwackenform. Sachs. Heft 1. Die Graptolithen, t. 2. figs. 2–7.

‡ Quart. Journ. Geol. Soc. vol. vii. p. 55.

§ The same must be said of *Grapt. lasus*, Nicol, described, but not figured, in the Quart. Journ. Geol. Soc. vol. vi. p. 64. Most of the specimens are scalariform impressions, and offer very little to distinguish them from *G. sagittarius*.

G. ludensis, therefore, only remains, as quoted by me in the list given in Prof. Nicol's paper*. It is accompanied however by another species, apparently an undescribed form, with cells closely set, each with a long decurved spine from its upper edge. I have called it *G. Flemingii*, and figures and a description are subjoined.

DIPLOGRAPSUS TERETIUSCULUS, Hisinger, sp. Pl. XXI. figs. 3, 4.

Prionotus teretiusculus, Hisinger, Lethæa Suecica, Supp. 2 (1840), p. 5. t. 38. f. 4.
G. teretiusculus, Scharenberg (1851), Ueber Graptol. t. 2. f. 17–32.
G. personatus, Scharenberg, ibid. t. 1. f. 12.
G. teretiusculus, Geinitz (1852), Verstein. Grauwack. Sachs. heft i. p. 26.

SPEC. CHAR. Cylindricus aut subcompressus, insuper et subter lineâ medianâ rectâ vel subundulatâ exaratus; cellularum oribus transversè oblongo-ovalibus, diametrum suum verticalem sese distantibus, simplicibus, nec ad marginem inferiorem prominulis, subtus in lineam impressam brevem utrinque excedentibus.

Cylindrical, rather quickly tapering at the small end, smooth, marked down the upper and lower side by an impressed median line, which is generally straight, but sometimes a little wavy between the two rows of cells. The mouths of the cells are transverse, oval-oblong, a little curved down on each side so as to be obscurely lunate, their edges not at all projecting from the general surface; they are placed nearly their own breadth apart from one another in the full-grown part, and there appear to occupy the whole width of the tube (in the young part they are smaller and more distant proportionally). From the base of the mouth on each side a short impressed line extends downward, but not so far as to the succeeding cell-mouth, and either parallel to the median line or very slightly inclined towards it. The surface shows transverse lines on all parts.

We have compared this well-marked species with excellent specimens, from the alum slate of Scandinavia, in the collection of the Geological Society. Hisinger's figure is a very bad one.

The axis of this species, as in *G. bicornis*, Hall, and some others of the same group, is narrower than the general thickness, so as in this case to be visible only as a longitudinal constriction or impressed line.

This Graptolite, like the *D. rectangularis*, M'Coy, which very possibly may also belong to the species we are describing, is remarkable for having the cell-mouths simply excavated in the sides,—the lower edge not at all projecting as it does in all the other foliaceous Graptolites; indeed, in this species the openings are a little sunk beneath the general surface, so as to render the interspaces somewhat tumid.

Locality. Glenkiln, Dumfriesshire. The species occurs also in Anglesea, N. Wales, in considerable perfection.

* Quart. Journ. Geol. Soc. vol. vi. p. 54 & 64.

Graptolites Flemingii, n. sp. Pl. XXI. figs. 5, 6, 7.

Spec. Char. Linearis, plures uncias longus, lineam latus, dentibus confertis; cellulis obliquis brevibus, canalem communem æquantibus, ore lato, insuper in spinam acuminatam satis longam decurvatam producto, subtus inermi.

Description.—Long, linear, about a line broad, the young part narrower. Edge closely dentate, the cells being about four in the space of a line, oblique, and not occupying in their depth above half or a little more of the entire breadth of the shaft; they are straight, not curved at their base, and are furnished at their upper edge with a strong acuminate spine, which is curved downwards almost from its origin and overhangs the wide concave margin of the mouth. The latter at its lower edge abuts directly against the succeeding cell, and is not at all produced. The curved spine is, in full-grown specimens, equal in length to three-quarters the breadth of the shaft; in younger and narrower specimens it is equal to it. Axis distinct, narrow.

The spines vary a little in degree of downward curvature, but they are never direct, nor are they so short as in *G. Chimæra*, Barr., a species with which ours is closely connected; moreover in that species the length of the cells is greater in proportion to the width of the shaft, and the lower edge of the mouth is shortly produced. We do not feel justified therefore at present in uniting them, but it is quite possible that other specimens may show that the Bohemian species varies in these characters. M. Barrande, on a cursory view of the fossil now described, considered it to be his *G. colonus*; but in that species, besides the spine being shorter, it is placed on the lower edge of the mouth, and the long cells have a curve at their base, as in *G. priodon*. It should be compared with the species figured as *G. Sedgwickii* by Geinitz (*loc. cit.* pl. 3. fig. 2).

Our numerous specimens present constant characters. We have figured with the usual full-grown form (fig. 5 *a*, 5 *b*) a specimen or two squeezed laterally (figs. 6, 7), in which the cells consequently appear oblique and elongated. These specimens have the cells longer, taking their origin nearer to the back of the shaft, which also shows a shallow depression down it, where the axis was placed. The spines are very much decurved. These obliquely crushed specimens show at the base of each cell the impression of the opening, or rather of the edges of the opening, into the common canal: this structure was first explained by M. Barrande, and is that which gives the scalariform appearance to the single graptolites. It is more completely shown in our figure of *G. laxus* (Pl. XXI. fig. 9), and is also figured by Geinitz without explanation (*l. c.* t. 2. f. 35, 36).

Loc. Balmae, Kirkcudbright, in great plenty. (Wenlock shale?)

Graptolites sagittarius, Linn. Pl. XXI. f. 8.

Prionotus sagittarius, Hisinger, Lethæa Suecica, Supp. p. 114. t. 35. f. 6.
G. incisus, Harkness, Quart. Journ. Geol. Soc. vol. vii. pl. 1. f. 8.
G. sagittarius, Geinitz, *l. c.* t. 2. f. 2–7.
G. Barrandei, Scharenberg, *l. c.* t. 1. f. 5–7.
G. virgulatus, Scharenberg, *l. c.* t. 1. f. 8–11.

This has been compared with good specimens in the Society's collection from Sweden, and no difference can be detected. Mr. Harkness has favoured the Geological Survey with an excellent suite, of all ages, and, in one or two, spines were observed projecting from the lower edge of the cell, as in Hisinger's species. Prof. M'Coy also quotes *G. sagittarius* from this district.

Description.—Young specimens have the breadth of the notches or cell-mouths greater than that of the shaft; in middle age the notches are considerably less deep, although the oblique lines of division between the cells extend far inwards and leave but a narrow canal; in old specimens, which are frequently 1 line broad and a foot long, the depth of the notches is about one-third of the whole breadth or scarcely so much. The spine in our best-preserved specimens is longer than in those we have seen from Sweden; but as so few spines are present, we cannot say if this is constant.

Localities. Glenkiln; Bran Burn; Duffkinnell, &c.

Note.—The species called *G. sagittarius* by Portlock (Geol. Rep. pl. 19. f. 8, and pl. 20. f. 1) has very narrow and crowded cells, placed very obliquely, and hardly projecting at all as distinct teeth. I find that Col. Portlock has proposed for it the name of *G. Conybeari* in MS. with a description as follows:—"The axial space wide and flat, the serratures closely pressed together, their points appearing very little beyond the axis."

Mr. Sowerby has used this name in his MS. Catalogues of the Collection of the Geological Society; and it will, I suppose, be generally adopted.

Pl. XXI. fig. 9.

Of *G. laxus*†, Nicol (Quart. Journ. Geol. Soc. vol. vi. p. 64), it is thought desirable to give a figure, in order that a comparison may be made with similarly compressed specimens of *G. sagittarius*.

These admirably show the scalariform appearance produced by the somewhat oblique compression of the canal and cells, as explained in Barrande's treatise on the Graptolites of Bohemia, p. 45–47. And I think that this condition is what has chiefly given rise to Prof. M'Coy's idea, that there is at the base of each Graptolite-cell a diaphragm which nearly closes the base. When the fossil is laterally compressed, the basal edges of the cells, which are placed obliquely by pressure, frequently run in straight lines as in fig. 9 *a*; when the compression has taken place more in the plane of the mouths, a double series of oval marks is the result, as shown in fig. 9 *b*.

Locality. Thornielee, Selkirkshire. Collected by Prof. Nicol.

DITHYROCARIS? APTYCHOIDES, n. sp. Pl. XXI. fig. 10.

This remarkable little fossil is figured rather to call attention to it than to assign it a true position. It is exceedingly like in form to a pair of the fossils called *Aptychus*, but there is a slight indentation in each plate, just at the umbo or inner angle (*), which does not

† See above, p. 388, note.

exist in *Aptychus*. It cannot be a bivalve shell, but most likely belongs to Crustaceans,—the Phyllopoda.

Loc. Duffkinnell, Dumfriesshire, in company with Graptolites.

EXPLANATION OF PLATE XXI.

Pterygotus problematicus.

Fig. 1 *a*. Part of the claw of *Pterygotus problematicus*, Agass., from the Upper Ludlow Rock of Hagley Park, Herefordshire:—this is probably the fixed finger, and shows the striated spines of unequal size.

Fig. 1 *b*. Some of the spines, magnified.

Fig. 2 *a*. From the same slab:—a portion probably of the spinous edge of the abdomen, with one of the lateral appendages (*) attached.

Fig. 2 *b*. The appendage, fig. 2 *a**, magnified, to show the radiating striæ and lateral teeth. This large spine or appendage may possibly be a terminal joint of one of the feet, pressed against the fragment, fig. 2 *a*, but not articulated with it.

Graptolites.

Fig. 3 *a*. *Diplograpsus teretiusculus*, Hisinger, sp. A cylindrical specimen from Anglesea, Collection of Mus. Pract. Geol. Natural size.

Fig. 3 *b*. ——— ———. The same, magnified.

Fig. 3 *c*. ——— ———. Lateral view, to show the cell-mouths. Magnified.

Fig. 3 *d*. ——— ———. A hollow mould in slate, from the same locality, much pressed in a longitudinal direction, so as to shorten all the cells and press them into a zigzag form.

Fig. 4 *a*. ——— ———. A compressed specimen, from Dumfriesshire. Natural size.

Fig. 4 *b*. ——— ———. The same, magnified;—the cell-mouths forming right-angled notches on the margin.

Fig. 5 *a*. *Graptolites Flemingii*, sp. nov., from S. Kirkcudbrightshire. Nat. size.

Fig. 5 *b*. ——— ———. The same, magnified;—the spines moderately decurved.

Fig. 6. ——— ———. A specimen much pressed laterally, so as to render the cells more oblique, and the spines more decurved. Magnified.

Fig. 7 *a*. ——— ———. A variety with less crowded cells, similarly, but more strongly compressed: the spines very much decurved. In this specimen, as well as the last, the impression of the base of the cells is marked by a transverse line. Natural size.

Fig. 7 *b*. ——— ———. The same, magnified.

Fig. 8 *a*. *Graptolites sagittarius*, Linn. A young specimen from Dumfriesshire. Natural size.

Fig. 8 *b*. ——— ———. The same, magnified: the cells occupy more than half the entire width.

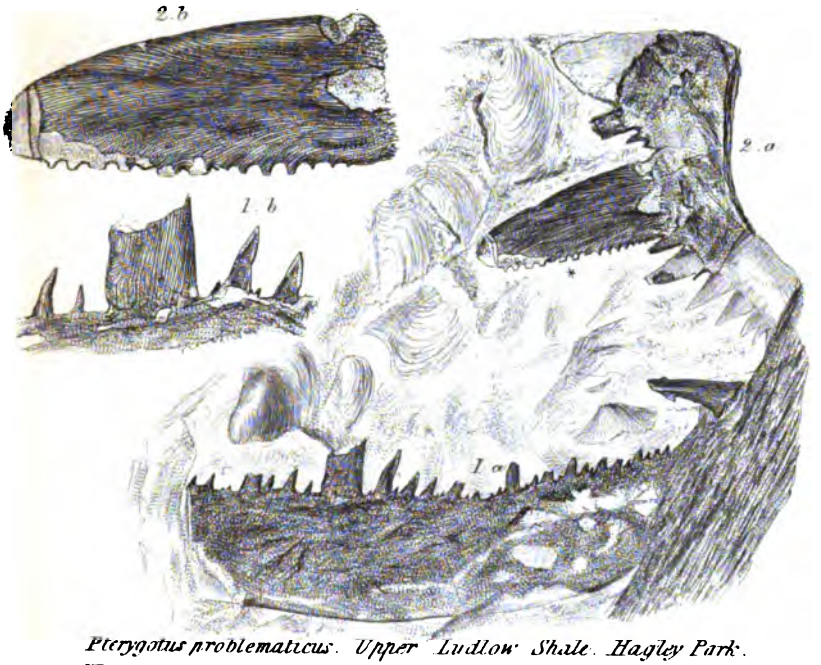
Fig. 8 *c*. ——— ———. An older specimen, from the same locality. Natural size.

Fig. 8 *d*. ——— ———. The same, magnified: some of the cells bear spines on the lower edge of their mouths.

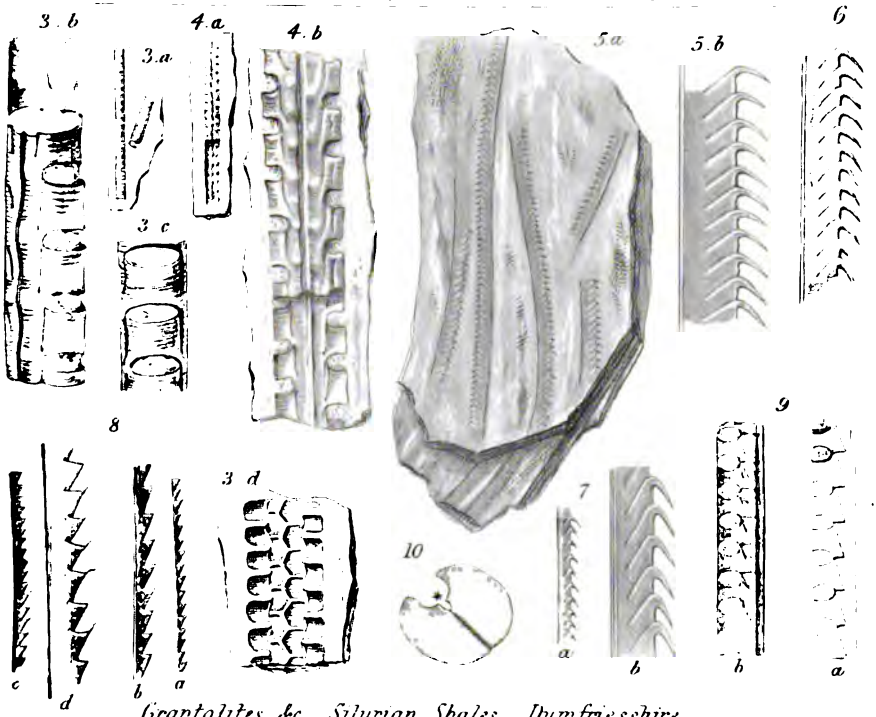
Fig. 9 *a*. ——— ———? (*G. lævis*, Nicol). Magnified view of an obliquely pressed specimen, showing the oval mouths and transverse impressed line at the base of the cells.

Fig. 9 *b*. ——— ———. Scalariform impression of the same species, showing the mouths and the oval openings from the base of the cells into the common canal.

Fig. 10. *Dithyrocaris? aptychoides*, sp. nov. Natural size. The valves are quite flat, and show the notch (*) at their upper angles.



Pterygotus problematicus. Upper Ludlow Shale. Hagley Park.



Graptolites &c. Silurian Shales, Dumfriesshire.

4. *On the* SILURIAN ROCKS *of the* SOUTH OF SCOTLAND, *and on the* GOLD DISTRICTS *of* WANLOCKHEAD *and the* LEAD HILLS.

By R. HARKNESS, Esq.

[Communicated by J. C. Moore, Esq., Sec. G.S.]

[Abstract.]

MR. HARKNESS considers that the mineral axis of the system of Silurian rocks in the south of Scotland is the syenitic mass of Criffel*. The rocks lying next to the syenite are in a highly metamorphic state, but wherever bedding can be traced, it is found that the strata on the south side dip to the south, and on the north side to the north; which last northerly dip (or to speak more correctly N.N.W. dip) continues with little exception to the northern margin of the Silurian rocks.

The lowest regularly stratified beds which can be observed on the north of Criffel are near Woodside Hill, in the parish of New Abbey, Kirkcudbrightshire, where the dip is N.E., but at no great distance to the west of this the usual N.N.W. dip obtains. By following these beds northward from Lochaber (where the syenite again occurs), an ascending section is procured for six miles, the dip exceeding 70°. The rocks consist of thick and thin greywacke sandstone (in contact with the igneous rock), frequently showing the laminæ of deposition, succeeded by thin-bedded flaggy greywacke, resembling flinty slate. Then follow in succession (at Longwood) greenish-grey, curved, laminated beds, intersected by calcspar veins,—a series of chloritic shales, interstratified with thin beds of fine-grained greywacke sandstone,—shales,—and lastly sandstone and flaggy beds, which form the hills up to the Nick of Bennerick.

On the opposite side of the vale of the Nith, in the county of Dumfries, a similar series of rocks occur, occupying a portion of the parishes of Torthorwald and Tinwald. The author regards these rocks as the base of the series dipping N.N.W. in the central portion of Dumfriesshire, and, with the beds which lie to the south, as forming the eastward continuation of the southern axis of this Silurian series. Upon these, therefore, Mr. Harkness conceives the beds to rest which were described in his former memoir† as occurring in the Glenkiln Burn. They consist of thick- and thin-bedded greywacke, with Annelid-markings in its upper part, followed by drab-coloured shales and anthracite,—then shales with Graptolites,—a great thickness of greywacke sandstone,—and lastly grey, green, and purple shales, the last sometimes showing ripple-marks and Annelid-markings. These coloured shales are exposed on the Garrell, Glenkiln, and Newlands Burns; and, by following the line of strike from the Newlands Burn westward (S.W.), the shales with Annelids are again met with at Parton slate-quarry, about six miles north of Castle Douglas and about twenty miles from Newlands. The shales are here much indurated, and there is a local disturbance of the dip. Succeeding these shales are greywacke sandstones, which are seen at Parton, and also

* See also Quart. Journ. Geol. Soc. vol. vii. p. 56. † *Loc. cit.* p. 49.

on the Water of Ae west of Glenkiln, and below the summit-cutting of the Caledonian Railway, N.N.E. of Glenkiln.

About Raecleugh, on the Evan Water, near where the counties of Dumfries and Lanark join, slaty beds occur, which the author has observed also at Benbuic (in the western part of Dumfriesshire), near the head of the Dalwhat Burn, in the parish of Glencairn. The surfaces of some of these beds are rippled, and bear Annelid-markings. These slaty beds are next met with twelve miles westward, near Barlae, in the parish of Dalry, Kirkcudbrightshire. Here the rock is identical in character with that at Benbuic, and the faces of some of the beds show ripplings and Annelid-markings, together with Graptolites and Fucoids.

The author considers this slaty rock to be the equivalent of the Grieston slate, described by Professor Nicol*, and to be the highest bed seen in Dumfriesshire. But by following up the section afforded by the Caledonian Railway, he finds the following succession in ascending order:—

1. Thick and thin greywacke sandstone at the summit-cutting before-mentioned. 2. Grey shales, equivalent to the grey slates of Benbuic and Barlae before-mentioned. 3. A great thickness of black shales, which are different from any rock occurring to the southward, and run E.N.E. into Peeblesshire, where they have been quarried for slate at Wrae in Glenholm parish, and also at Stobo. They are seen again, westward of the Railway at Glenochar, and, though containing no fossils, Mr. Harkness believes them, from their resemblance and position, to be the same as the graptolitic Cairn slates on Loch Ryan, described by Mr. J. C. Moore†. And 4., a conglomerate containing fragments of the black shale in great abundance. This is apparently identical with the conglomerate found in a quarry near the base of the hill at Wrae, and underlying the limestone described by Professor Nicol‡. The author observes that here the dip of these beds is towards the south, but, as the black shale comes on immediately to the northward with the usual dip, it is probable that the conglomerate and limestone have been let into their present position by a fault.

Having thus reached the zone of the Wrae limestone, Mr. Harkness dwells upon the close relation of this limestone with that of Craighead, and with the Silurian rocks of the south-west of Ayrshire, lately described by Sir R. I. Murchison§, and observes that the conglomerates of Kennedy's Pass, accompanying those Ayrshire beds, contain fragments of Silurian rocks similar to those found southward, and also fragments of syenite resembling that of Cairnsmuir and Loch Doon, which the author considers to be of the same age as that of Criffel. Hence he infers that the elevation of the Silurian rocks to the south had taken place previously to the formation of these conglomerates.

Mr. Harkness states that he has succeeded in tracing the anthracite

* Quart. Journ. Geol. Soc. vol. iv. p. 204, and vol. vi. p. 53.
† *Ibid.* vol. v. p. 7.
‡ *Ibid.* vol. iv. p. 203.
§ *Ibid.* vol. vii. p. 139 *et seq.*

bands of Dumfriesshire, described in detail in his former memoir, through the greater part of Selkirk to the neighbourhood of Galashiels; and he considers that the opinion he formerly offered on the probable repetition of the anthracitic bands and their accompanying greywacke beds by means of faults* has been confirmed by his subsequent observations. In calculating the thickness of the formation, the author takes the area included between the most northerly band of anthracite at Greskin, about four miles north of Beatock, and the black shales at Elvanfoot that lie below the conglomerate on which the Wrae limestone reposes, as comprising the great bulk of the strata which make up the series. The distance between these two points is six miles across the strike, for which distance the dip is on an average 70° to the N.N.W. From these data Mr. Harkness gets a thickness of about 24,000 feet, and, estimating the above-mentioned conglomerate and the deposits about Girvan, together with the lowest greywacke sandstones next the syenite, at about 6000 feet, he gets a total thickness of about 30,000 feet for the Lower Silurian rocks in the south of Scotland; an estimate not greatly differing from that of Professor Nicol†.

With regard to the fossils,—in addition to those mentioned by the author in his former communication, he has found in the shales connected with the anthracite-bands *Diplograpsus teretiusculus*, Hising., and *D. ramosus*, Hall; the former at Glenkiln, the latter at Hartfell, Dumfriesshire‡.

In these graptolite-shales he has in vain sought for the *Graptolites priodon* (=*G. ludensis*, Murchison), first quoted by Professor Nicol from the Grieston slate, and above or below which bed it has not yet been found in Scotland. It does not occur in any of the strata further south, unless it be at Balmae, Kirkcudbrightshire, associated with a new species, the *G. Flemingii*, Salter, and numerous Wenlock fossils. Mr. Harkness remarks too on the occurrence in the black shales of Loch Ryan of several species of *Graptolites* which are equally characteristic of the anthracitic shales of Dumfriesshire, supposed by him to occupy a very much lower horizon.

Finally, in the coloured shales of Benbuic, Dumfriesshire, and the similar beds at Barlae, Kirkcudbrightshire, the author has detected Annelids and Fucoids (*Nereites* and *Palæochorda*).

Mr. Harkness no longer refers these Silurian rocks of Dumfriesshire to the Caradoc age, as in his former memoir, but he believes them to lie below the representatives of the Llandeilo flags, as suggested by Sir R. I. Murchison§; and the whole evidence goes to show that some of the rocks of the south of Scotland lie very far down in the Lower Palæozoic series, occupying a position equivalent to the Skiddaw slate described by Prof. Sedgwick.

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* *Loc. cit.* p. 51. † Quart. Journ. Geol. Soc. vol. vii. p. 58.

‡ See Mr. Salter's observations on the Graptolites of the South of Scotland, *supra*, p. 388.

§ Quart. Journ. Geol. Soc. vol. vii. p. 162.

The author then describes the occurrence of gold in the Lower Silurian rocks. It is found disseminated, in small foliaceous particles or in round grains, in the quartz-veins which traverse the greywacke sandstone and shale in a direction generally at right angles to their strike; and also in the detritus of the same rock. A specimen weighing 240 grains was lately found. The district furnishing the gold lies to the north of the zone of black slate which runs from Stobo through the summit-cutting of the Caledonian Railway and Glenochar in the direction of Cairn Ryan. It is greatly disturbed, not only by the quartz-veins, but by dykes of felspar and greenstone; and the dip is the reverse of that which usually prevails. Mr. Harkness believes that the occurrence of gold is not connected with any particular portion of the Silurian series, but rather with the presence of the quartz-veins and the influence of the plutonic rocks.

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5. *On the* Ornithoidichnites *of the* Wealden.

By S. H. Beckles, Esq.

[Communicated by Sir C. Lyell, V.P.G.S.]

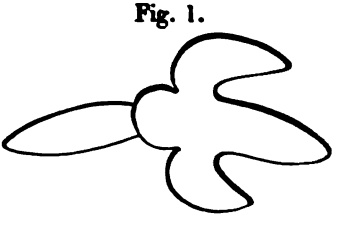
[Abstract.]

Since the publication in January 1851* of the notice of the peculiar trifid bodies occurring in the Hastings rock, the author has added several specimens to his collection, some of which appear to afford additional evidence in favour of the opinion of their being natural casts of the prints of birds' feet.

To the west of St. Leonard's† the specimens occur on small blocks lying on the beach and subjected to tidal action. These as yet have presented solitary ornithoidichnites only. To the east of Hastings, however, the trifid bodies are found under more favourable circumstances. At a distance of between six and seven miles from St. Leonard's immense blocks of stone, some of them several tons in weight, lie for some distance along the beach in confused masses, immediately at the base of the cliff and above high-water-mark. On these blocks the ornithoidichnites are frequently found, and sometimes in pairs or groups. The following specimens have been selected as being of most interest.

Fig. 1 is the outline of one of two of these bodies which were found on the surface of a block measuring 7 ft. 3 in. by 4 ft. They differed from the usual form in having a posterior elongation, which was about two-thirds the length of the "trifid," and less than half its height,—projecting

Fig. 1.



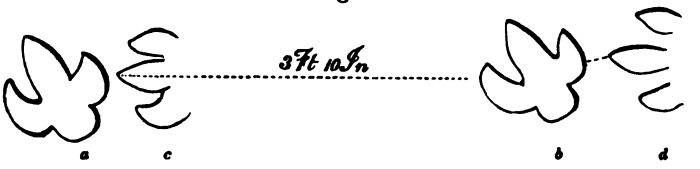
* Quart. Journ. Geol. Soc. vol. vii. p. 117.

† One specimen was obtained also in digging the Railway tunnel between St. Leonard's and Hastings.

therefore less prominently from the surface of the stone. The two bodies were placed one in advance of the other; they had a uniform direction, with a slight lateral inclination, one to the right and the other to the left. The distance between them—from the middle "toe" of the one to the "heel" or central protuberance of the other—was 3 ft. 4 in.

Fig. 2 exhibits the relative position of four "trifids" that were exposed on a block measuring 9 ft. 4 in. by 4 ft. Two of t m, *a*, *b*,

Fig. 2.



presenting the ordinary form of these curious bodies, were parallel with each other, and had a uniform direction. The other two, *c*, *d*, pointed in a different direction to that of the other pair, and followed each other in a right line at a distance of 3 ft. 10 in. (measured from the extremity of the longest toe of the one to that of the other). In this last pair the heel-like central protuberance was wanting, a condition suggesting the idea that the original imprint might have been made by a bird (?) passing quickly over the ground. On another block, lying at a short distance from the above, was found a similar pair of heel-less Ornithoidichnites, one in advance of the other, and so much resembling the last-mentioned pair, *c*, *d*, in every particular, even in the distance between them, or length of the stride, that they had every appearance of being the continuation of the same track.

In every instance these trifid bodies occurred on that surface which was the under-plane of stratification when the blocks formed part of the cliff.

The distance separating the "trifids" when occurring *in serie* varies from rather more than 2 feet to 3 ft. 4 in. (measured from the toe of one to the heel of another). In consequence of this distance between the ichnites, none of the blocks that came under the author's observation as exhibiting one or more specimens could, from their limited extent, have contained more than the number actually observed upon them.

The author observes, that having also discovered one example at White Rock and another at the Sluice which is about ten miles to the west of St. Leonard's—the extreme point in this direction where the organic remains of the Wealden are obtained, he has detected these singular trifid bodies throughout the entire section of the Wealden on the Sussex coast, an extent of nearly eighteen miles.

6. *Additional Notes on the* Red Sandstones *of* Nova Scotia.

By J. W. Dawson, Esq.

[Communicated by Sir C. Lyell, V.P.G.S.]

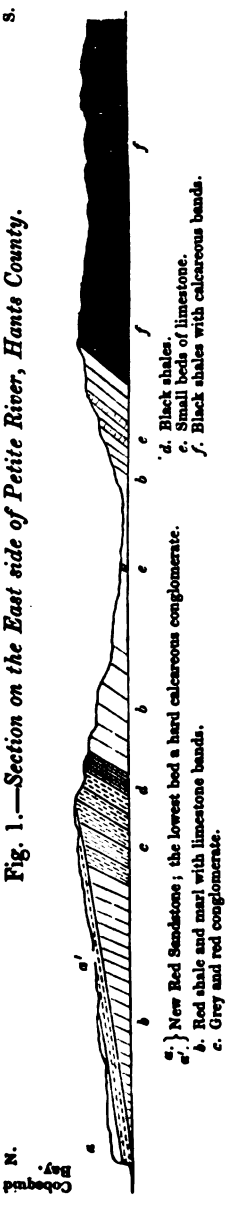


Fig. 1.—*Section on the East side of Petite River, Hants County.*

In a paper on the New Red Sandstone of Nova Scotia, read before the Society, June 1847*, in which I endeavoured to separate the true New Red Sandstones skirting the Bay of Fundy from the red beds associated with the gypsiferous series and other members of the Carboniferous system,—after having traced these beds to the mouth of the Shubenacadie, and again observed their continuation in Cornwallis and Horton, west of the estuary of the Avon,—I remarked that, while the intervening county of Hants is occupied chiefly by carboniferous deposits, there are on its north shore patches of nearly horizontal sandstone which might belong to the New Red.

I had in the past summer an opportunity of examining these beds at Walton (Petite) and other places, and was much gratified by finding that the New Red might be traced, as a narrow and occasionally interrupted band, from the mouth of the Shubenacadie nearly to the mouth of the Avon; thus connecting as far as possible the distinct patches of New Red described in my former paper. At some points also I found very distinct coast-sections, showing the unconformable superposition of the New Red on the Lower Carboniferous beds. A good instance of this occurs at Petite River (see figs. 1 & 2).

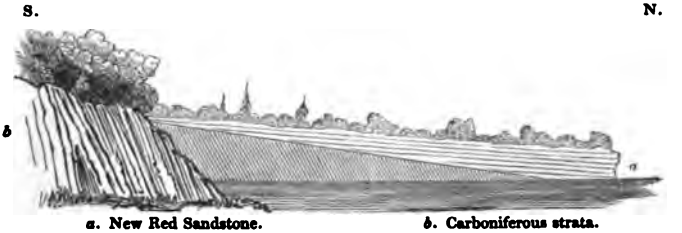
Near the mouth of the river the Lower Carboniferous formation appears with the same characters observed at Windsor and on the Shubenacadie. It includes a large bed of gypsum, extensively quarried for exportation, and a bed of limestone with veins of oxide of manganese, apparently the geological equivalent of the Black Rock limestone on the Shubenacadie. In the neighbourhood of these beds the softer rocks have been denuded and do not appear. Still nearer the mouth of the river, however, there is a distinct section, showing black shales, with calcareous bands, dipping at a high angle to the south, and underlying the beds above-mentioned. In a short space these beds become contorted, and then dip steeply to the north, fig. 1, *f*, *f*. I

* Quart. Journ. Geol. Soc. vol. iv. p. 50.

found no fossils in these shales; but in their continuation eastward, at Noel, they contain a *Lepidodendron* identical with one found in the similar shales of Horton Bluff. The position, as well as the mineral character of these shales, leaves no doubt that they belong to that remarkable band of pseudo-coal-measures found in the lowest part of the Lower Carboniferous series at Horton, Windsor, Rawdon, Five Mile River, Antigonish, Strait of Canseau, &c., and described in papers formerly read before this Society *. Succeeding these black shales, in ascending order, the Lower Carboniferous rocks are seen in the above section, fig. 1. These beds probably underlie the gypsum and limestone which would recur on the north side of the anticlinal formed by the black shales if the section extended sufficiently far. Before reaching the extremity of the point on the east side of the river, however, the edges of the beds sink to the level of the sea, and the lower members of the New Red are unconformably superimposed upon them. It is a somewhat instructive fact that the beds of the underlying series are at this place both redder and softer than the overlying New Red Sandstone.

Fig. 2 shows the appearance of the section on the west side of the mouth of the river, as viewed from a distance.

Fig. 2.—*Section on the West side of the Mouth of Petite River.*



a. New Red Sandstone. *b*. Carboniferous strata.

At Salter's Head, near the mouth of the Shubenacadie, the sea-cliff shows a considerable thickness of the New Red, which is there a soft bright red sandstone, some of the beds containing calcareous sandy concretions, which cause them to weather with singularly uneven surfaces. In these respects they perfectly resemble the rocks of the same formation seen between the Shubenacadie and Truro. The New Red does not appear, in any part of this coast, to extend more than between one and two miles from the shore, and in most places its breadth is much more limited, being often only a few hundred feet.

When in Hants County last summer, I revisited the great mass of gypsum at Big Plaister Rock on the Shubenacadie, described by Sir C. Lyell, in company with whom I visited it in 1842. Since that time a large part of the mass has been removed by the quarrymen, and the highest part of the rock, about 100 feet in height, seemed tottering to its fall, the excavations of the quarry having completely

* See Quart. Journ. Geol. Soc. vol. vi. p. 347 and note.

undermined it. The removal of the gypsum had exposed, on the northern side of the quarry, some bands of flaggy bituminous limestone, nearly in a vertical position. These I found to contain abundance of flattened specimens of *Conularia quadrisulcata*, which occurs also in the gypsiferous rocks at Windsor and at Cape Breton. These fossils mark distinctly the true age of this great mass of gypsum, which, from its isolated position and singular structure, could not be accurately determined on stratigraphical grounds. From the appearance of this mass of gypsum in its present state, I have no doubt that it consists of thick parallel laminæ, or thin beds, contorted in an extraordinary manner and closely cemented together. In the highest part of the cliff these bent laminæ assume the form of a huge cylinder, incomplete only on its lower side.

I was informed that, since my last visit, the sandstone cliff of Eagle's Nest, opposite the "Big Rock," had slipped into the river, leaving a clean face of rock somewhat lower than the former cliff.

I may also mention that the high cliff at Two Islands, on the opposite side of the Bay, of which a section is given in my paper on the New Red Sandstone *, has fallen, burying the most interesting part of the section under the mass of trappean debris, which will not for several years be removed by the tides of the Bay.

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7. *On the* Geology *of the* Lake of the Woods, South Hudson's Bay. By Dr. J. J. Bigsby, F.G.S.

[Plate XXII.]

In the following pages it is intended to describe the nature, position, and relations of the rock-formations of the Lake of the Woods in South Hudson's Bay, comprising a part of the commercial route from Canada to Rupert's Land, and the eastern terminus of the Boundary-line between the Possessions of Great Britain and the United States, where it passes along the 49th parallel of latitude from hence to the Rocky Mountains.

This lake is not without its claims to the attention of the Geological Society.

It is here that the igneous and metamorphic rocks, which ever spread the half-drowned wildernesses of East Hudson's Bay, have their western termination (for this latitude);—here they sink out of sight and are replaced westwards by sedimentary rocks.

By an examination of the first-mentioned classes of rock on the lake, we learn that they are generally conformable to the of crystalline strata which extend from hence [illegible] —to the River Mississippi in lat. 43°. This g[illegible] has a general strike to the W.S.W.

The Lake of the Woods is 400 miles round b[illegible] 75 miles in extreme length and breadth. It

* Quart. Journ. Geol. Soc. vol. i[illegible]

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irregular, is best learnt from a glance at the accompanying Map, Pl. XXII.

It is divided into three parts (each having its own name) by a promontory, 40 miles in direct length, which, beginning at the south-eastern angle of the lake, extends N.W., and approaches within half a mile of the western shore 30 miles from the northern extremity of the lake.

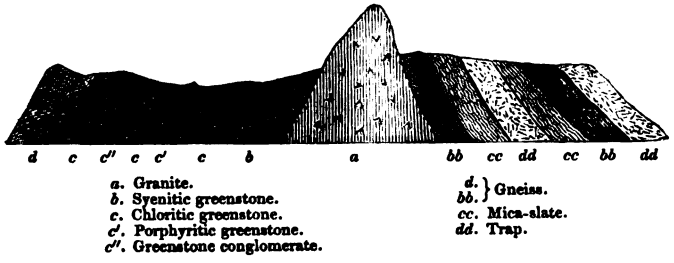
This promontory first separates Whitefish Lake, and then Lake Kaminitic, or the Lake of the Woods proper, from the Lake of the Sand Hills, the entrances to each being barred by islands.

Whitefish Lake has never been properly examined. I have seen it from three points 25 miles apart, and noticed several lofty basaltic islands. It is supposed to be 120 miles round.

The south and south-west side of Sandhill Lake has few or no islands, and its shores sweep around in large uniform curvatures faced by sand-hills or gravelly banks, which sink behind into rice-marshes or wide-spreading lagoons. Westward the land rises very slowly, until at 70 or 80 miles from the lake it becomes a grassy plain; and wet savannahs, with clumps of fine trees here and there, prevail largely about Monument Bay. The greenstone cliffs and high pine-covered islands of the Kaminitic render this part of the lake extremely picturesque.

Although, from the marshy, woody, or shattered state of the country, its rocks can only be examined at intervals, still their nature and disposition are easily recognised, especially when we notice the directions and dips of the metamorphic rocks on a good map. These are in two groups, one on each side of a mass of granite, and dip respectively northerly and southerly from it at a high angle (see fig. 1). This granite, which I consider to be the axis of an anti-

Fig. 1.—*Diagram of a section across the Lake of the Woods, passing near Pipestone Island, Lake Kaminitic.*



clinal ridge, comes from the west main in and to the north of Monument Bay, crosses, with an E.S.E. trend, the centre of the lake, chiefly (so far as swamps and other local hindrances allow us to see) along the south shore of the great promontory, occupies most of the adjacent islands in Sandhill Lake, together with much of its S.E.

coast, and extends as far as Lake La Pluie*. It always forms hummocks, ledges, and low bosses, and sometimes overspreads many square miles with little change, particularly in the west, as far as the extensive swamps will allow us to see. This granite is grey and pale red, and the mica is black. It is coarsely granular, and only porphyritic when it forms a vein. Although through its course of 100 miles, from Monument Bay to River Neketchawonan at the N.E. end of Lake La Pluie, its mineral composition varies from place to place, yet it always returns to one particular type (that of Gravel Point).

In this district granite is always the lowest rock, and traverses all the other rocks. It is frequently gneissoid.

A distinct form of granite is met with on the east side of Lake Kaminitic, about the mouth of the River Anagoyahmé, but I only saw a small quantity *in situ*.

The metamorphic or stratified rocks, few in number, and altogether different on the different sides of the anticlinal, are gneiss, mica-slate, hornblendic, chloritic, and syenitic greenstone, and greenstone-conglomerate. They flank the granite, as we have before said, on both sides,—those on its north side (greenstones principally) dipping W.N.W. for the most part, but sometimes N.W. and N.; sometimes vertical, and, at Isle à la Crosse, with a S.E. dip; the last observation, however, is perhaps inaccurate †.

In Lake Kaminitic the E.N.E. and N.E. strike (*normal* ‡ for the countries on the immediate south) is very conspicuous in the syenitic and conglomerate greenstones.

But in Sandhill Lake, on the south side of the granite, the stratified rocks dip, with small occasional deviations, to the S.S.W.,—a direction resulting from the form and position of the intrusive rock.

At the S.E. end of Sandhill Lake, regularity of stratification is lost for 300 square miles, as will be afterwards shown.

These observations on dip and direction were made with the compass planted on the rock, and were more numerous than set down on the Map, Pl. XXII. They nearly coincide with the only two notices of strike, &c. in this lake given by Professor Keating §, Geologist to the Expedition to the River St. Peter's under Col. Long.

* Not included in the accompanying Map. See Map of Canada, Quart. Journ. Geol. Soc. vol. vii. pl. 14.

† The magnetic variation in this lake is 5° to 7° E.

‡ In the neighbouring Lake La Pluie, which is 300 miles round, and is based on gneiss, mica-slate, chlorite-slate, &c., out of 120 observations taken in all parts of it, only fourteen deviated considerably from a W.S.W. or W.N.W. strike, and almost all these occur in chlorite-slate. The W.S.W. strike is by far the most common strike in Lake La Pluie, as well as along the 220 miles of lake and morass south-eastwards to Grand Portage, Lake Superior. If we add to this similar statements respecting Lake Superior, made by MM. Foster and Whitney, and by Dr. Dale Owen for 150 to 200 miles, south of Lake Superior, in the State of Wisconsin, we shall see that the general trend (with local variations) of all the metamorphic rocks from the River Winnepeg for 700 miles south is W.S.W.,—a fact of great interest, as indicative of an enormous breadth of uplift.

§ That near Rat Portage coincides exactly.

With regard to the metamorphic rocks, the gneiss is only the granite interleaved with mica, and so rendered more or less slaty. Its mineral changes are similar to those of the granite.

Gneiss occupies the whole western shore of Lake Kaminitic up to near the River Winnepeg, and is also the frequent associate of granite in other parts of the lake.

Mica-slate is found extensively on the south shore of the Promontory and in the islands off Shebashca. It passes into and is interleaved with gneiss and a very black trap.

Greenstone is perhaps the most abundant rock in Lake Kaminitic. It is commonly impregnated with chlorite; but the proportions of this earth vary insensibly. Where there is much, it is in fine, shining, wavy or very tortuous foliations, interspersed with small nodules of the rock in concentric layers. This is well seen on the north-east shore five miles from the Rat Portage. The greenstone is very chloritic at intervals along the north side of the great Promontory, and especially on some islands near the Isle of the Yellow Girl. On these islands are veins of chlorite-earth 6–9 inches wide, used by the Indians for making pipe-heads. When the rock is less charged with chlorite it becomes almost massive. In several places for some square miles along the eastern shore of Kaminitic (as for instance a few miles north of Anagoyahmé River), the greenstone is rendered porphyritic by the presence of crystals of white felspar; and in some districts, each from 5 to 6 miles in length, along the north shore of the Promontory, from Red Cliff Bay to the Portage des Bois, it might be called syenite, on account of the gradual introduction of innumerable beads or drops of glassy quartz.

Greenstone-conglomerate appears twice in Kaminitic, but not under the same conditions. The northern band stretches E.N.E. from an island near the River La Platte, on the west shore, to the corresponding point on the north-east shore. On this island it wears a peculiar form. It contains many round black masses of the size of pigeons' eggs, like Lydian stone, and as hard and close in texture; but the great body of the rock is made up of large, oblong, angular masses of pale speckled greenstone, which lie with their length parallel to the strike. These appear on the weathered surface of the rock, but, on breaking it up to obtain specimens, they are seen to pass into a slaty structure, and become continuous with the cement of the conglomerate, as in Lake Superior, &c.

The chloritic greenstone-conglomerate about Portage des Bois, south of that just described, occupies a space twelve miles long northwardly, by six broad. Both the nodules and the paste are greenstone; the latter is darkest in colour. The nodules are here rounded, and vary in diameter from 1 to 15 inches. It was curious to observe that many of them were broken into several fragments from the effect of heat or by some external force, which however had not widely separated them (see fig. 2).

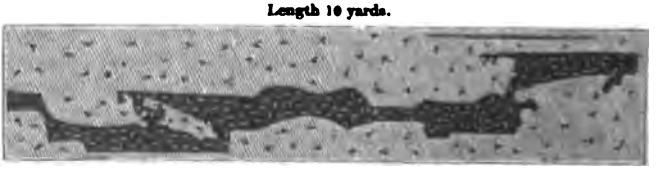
Proceeding now to Sandhill Lake, we observe how regular, and often how minute, are the interleavings of gneiss, mica-slate, and dark compact greenstone along the greater part of the Promontory and its

isles; but when we come to the south-east angle of this lake, these rocks (granite and gneiss being substituted for mica-slate) over an irregular space of about 300 square miles are so mutually involved and interpenetrated, and so intimately mixed up together, that it is impossible to give any but the most general account of their disposition, however plainly seen and carefully observed on the spot. In some places (Portage Mouillé, &c.) they are in narrow interleavings of no constant direction. In another (around Broken Road River) the granite, for large spaces, traverses dark greenstone in a thousand tortuous masses, tongues, and slender veins.

Fig. 2.—*Sketch of a broken fragment of Greenstone* (18 *inches by* 8) *in Greenstone-conglomerate at Portage des Bois.*

Veins of granite and quartz, and shapeless or lenticular masses of hornblende, rendered impure by a fine admixture of white quartz, are abundant in all these rocks; but as such appearances are common elsewhere, they are not here noticed in detail. Two veins of epidotic trap in granite, met with in an island near Portage Mouillé, were so artificial in appearance that I sketched them. One of these is represented by fig. 3. The isolated needle of trap in fig. 3 is perhaps connected with the contiguous vein of that rock.

Fig. 3.—*Ground-plan of a portion of a Trap-vein in Granite near Portage Mouillé.*



At other places (Turtle Portage, &c.) the whole country within view consists of massive trap.

Precisely the same appearances may be seen in Lake Superior near Gros Cap, and in Lake Huron between the Rivers Thessalon and Missisaga. These foldings and irregularities seem to be the result of external force.

In no part of the Lake of the Woods were any traces of metallic ores discovered, although carefully looked for.

We have yet to notice the limestone of the Lake of the Woods. It was not seen by me in juxtaposition with the crystalline rocks just described, but in mere shreds of strata, some miles off, in a low country, and buried beneath mounds of quartzose sand, clay, and immense assemblages of blocks from the north,—a country first denuded and then filled up with foreign debris*.

The limestone, whether fixed or loose, is only found on the south and west shores of Sandhill Lake. Near the south side of Driftwood Point, a little to the south side of Reed River, and at a third spot within the mouth of Rainy River, where dry banks replace the rushy swamp of the lake, there are (half buried in gravel) square, sharp-edged angular slabs and blocks of deep straw-yellow limestone, of a fine close grain.

Each of these fixed masses is from 10 to 15 feet broad, and 3 feet deep. They are all cracked and fissured by the intense cold of the climate. For several miles around these points, as well as elsewhere, the beaches are strewn with loose, flat, shingly fragments of limestone, which are largest and most numerous in the immediate vicinity of these points. They seem to have resulted from the action of the weather, ice, and waves. Together with these fragments occur travelled blocks of crystalline rocks.

I saw this same yellow limestone strewn plentifully over the west arm of Rainy River Bay, and on the shores of Elm Island.

On the right bank of Rainy River, not far from its mouth, are the fixed remains of an unfossiliferous calcareous breccia, consisting of yellow fragments in a brick-red paste.

My reasons for thinking these patches of limestone to be fixed, are—first, their position and aspect; secondly, the peculiar form of the coast on which they are found, which is usually indicative of the presence of sedimentary rocks; and thirdly, my being aware that on the west limestone shows itself as soon as the elevation of the ground will permit. The abundant, well-preserved, and often large fossils of this limestone (principally casts) show that it belongs to the Upper Silurian age; but to which particular division Mr. Salter, of the Museum of Practical Geology, who has kindly examined them, says that it is at present impossible to determine. The condition of the fossils shows that the animals must have died *in situ*.

My time having been always limited, I was only able to collect specimens of the following organic remains:—a very small and elegant *Phacops*; small *Orthocerata*, with wide chambers; minute Encrinital columns; various Corals, especially the *Favosites Gothlandica* and *Cyathophyllum*; *Murchisonia*, *Pentamerus Knightii*, *Leptæna*, *Avicula*, *Atrypa*, and *Spirifer*.

The following is a general view of the outlines of this calcareous basin.

* See Dr. Bigsby on the Drift of the Lake of the Woods and South Hudson's Bay, Quart. Journ. Geol. Soc. vol. vii. p. 215 *et seq.*, and Map, Pl. XIV.

Its northern limit in the Lake of the Woods is the south side of the great Promontory and its adjacent islands.

Eastward it is met by granite and gneiss about Windy Point, and is buried under rice-marshes.

The western boundary is only to be found in the far west on the east flank of the Rocky Mountains.

Southward it probably underlies the whole course of Rainy River, eighty miles in length, with the exception of a few outcropping bosses of gneiss and greenstone; it advances also three miles into Lake La Pluie; making thus a total stretch, north and south, of 110 miles.

I am led to believe that limestone underlies the greater part of the Rainy River tract, from its universal prevalence in slabs and shingle, from the uniform depth of the river, and the great fertility of the country it traverses.

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8. *On the* GEOLOGY *of the* SOUTHERN PORTION *of the* PENINSULA *of* CANTYRE, ARGYLLSHIRE. By JAMES NICOL, F.R.S.E., F.G.S., Professor of Mineralogy and Geology, Queen's College, Cork.

[Plate XXIII.]

THE peninsula of Cantyre forms one of the most anomalous features in the physical conformation of Scotland, whether we regard its geographical or geological peculiarities. The mountain ridges which give their character to other parts of the country have all, more or less, a direction from north-east to south-west. On the other hand, this peninsula runs nearly north and south from the Crinan Canal to the Mull, a distance of fifty-five miles, with an average breadth of only six to eight miles. It thus forms a narrow ridge of no great elevation, separating the Firth of Clyde from the open expanse of the Atlantic, whose waves during storms from the west beat with awful fury on its western shores. None of its mountains rise high, and in some places it is almost separated into several islands by low transverse valleys. Thus at Loch Tarbet the isthmus is only about a mile in breadth, and both there and at Campbeltown a depression of a few feet would convert it into several detached islands; which was probably its condition at no very remote geological date. Although forming a portion of the Scottish Highlands, its termination lies further south than some parts of the north of England.

The most remarkable geological feature of this district is the sudden extension to the south of the mica-slate formation, which, after running nearly in a direct W.S.W. line from the east coast at Stonehaven through the whole Highlands, bends sharply round to the south, and runs down to the extreme point of the peninsula. At the same time, the clay-slate, which had hitherto accompanied it, also turns south-east round the granite of Arran, and does not again appear in connection with the mica-slate. In all geological maps also the Lias formation is marked as occurring in this place, forming as it were a

Limestone
Tertiary & Recent
Red Sandstone
Coal Measures
Mica Slate
Igneous Rocks
GEOLOGICAL MAP
OF THE
Southern Extremity
OF
CANTYRE.
Killipoll
Ronachans
Knock Scalbert
Ballavains
Loch Ruag
Swarbie
Killchenzie
Kilhousland
Braskonul
MACHRIHANISH BAY
LAGGAN
Campbeltown
CAMPBELTOWN BAY
Davar I
Machrihanish
Lime Kilns
Kildalloig
Ballimeanoch
Blackfield
Ben Gullion
Kilkivan
Lossit
Tirfergus
Loch Sunnidie
Tainbeg
Killellan
Fuachaig
Achinhoag
Machariach
Southend
Strone
Kells
Balliemichill
Light House
Dunaverty
Mull of Cantyre
Scale of Miles
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connecting link between the newer rocks of Ireland and those remarkable secondary deposits in the Western Isles, described in the valuable memoirs of Sir R. Murchison and Professor Sedgwick*.

It might have been expected that these peculiarities would have attracted some geologist to visit and describe this portion of Scotland. This, however, has not hitherto been the case, and no complete account of the geological structure of Cantyre has ever yet been published. Some incidental notices of particular points may be found in the Mineralogical Travels of Professor Jameson, and Dr. Macculloch makes a few short references to it in his work on the Western Isles; the latter also published a description of the Porphyries of Davar Island in the Transactions of the Society†. In the summer of 1850 I spent a few weeks in the vicinity of Campbeltown, and found many very interesting geological phenomena well exposed in that neighbourhood. Some short notes of my observations were communicated to the Meeting of the British Association at Edinburgh in August 1850, and I had intended to communicate a fuller account of them to the Geological Society, but always delayed in the hope of being able to render them more complete by again visiting the locality; but I have hitherto been prevented doing so, and think it better to submit them in their present form. My observations do not embrace the whole peninsula, but refer only to its southern extremity, or the region extending from the Mull of Cantyre to a few miles north of Campbeltown, a tract about fifteen miles in length by ten or twelve in breadth. As I was not able to procure an accurate geographical map of the district, or even a map of any kind on a large scale, it was not possible to represent its geological structure correctly, and the sketch map that accompanies this paper (Plate XXIII.) must be regarded as merely a first approximation to a geological map. When I began to examine the district, I believed Dr. Macculloch's map to be a far more accurate representation of the distribution of the rocks than it proved to be on experience. It was only after I found that it was wholly untrustworthy that I endeavoured to supply the deficiency, and consequently was less able to do so correctly than if I had kept this object in view from the commencement of my researches.

In describing the geology of this district I shall begin with the oldest or fundamental rock. This is the mica-slate, which, as shown by the map, occurs in two detached regions‡. The first of these near Campbeltown is connected with the large mass of this rock which extends northward throughout the peninsula. It is almost divided into two by the loch or bay of Campbeltown, but beds of mica-slate appear in various parts of the low ground, rendering it probable that the rock extends continuously from Ben Gollion on the south to the hills on the north side of the bay. The second portion forms the wild country in the south-west of the peninsula round the Mull. In both districts the

* Trans. Geol. Soc. 2 Ser. vol. ii. p. 293; ibid. p. 353; vol. iii. p. 21; ibid. p. 125.

† Trans. Geol. Soc. vol. ii. p. 423.

‡ A third small portion of mica-slate is seen in the bed of the stream and the low grounds above Southend Church, but too inconsiderable to be worth noticing separately. See Map.

mica-slate differs considerably in its mineralogical characters from the rock so-named in the more central parts of the Highlands. Occasionally, as in the hills north of Campbeltown, it is a fine lustrous mica-slate, especially on the planes of lamination, but even then on a cross fracture it appears very arenaceous. More often it resembles a grey micaceous sandstone, and many hand-specimens might readily be mistaken for such a rock, or for varieties of greywacke. This is the general character of the mica-slate in Ben Gollion south of Campbeltown. In that mountain it is generally a reddish or yellowish grey laminated rock, consisting of fine quartz or felspar sand, with larger grains of quartz and very fine scales of a mica-like mineral, but which is not, as it seems to me, a true mica. In other cases the mica is replaced by a mineral more resembling talc, but mixed in such minute scales with the other constituents that I have not been able to determine its true nature. In other varieties fine folia of hæmatite or specular iron take the place of the mica. Indeed, I am inclined to think that true mica-slates are rather the exceptions in this district, and that probably some other name should be adopted for these rocks. In Ben Gollion also some of the beds show, when weathered, a distinct double lamination, intersecting at an acute angle, and more resembling the cleavage so common in the Silurian rocks than any structure I have ever observed in true crystalline strata.

In the mountains near the Mull many beds in the mica-slate form a kind of semicrystalline gneiss, bearing the same relation to this rock that the mica-slate does to that of the West Highlands. In this southern district the mica-slate is highly ferruginous, and imparts a strong chalybeate taste to the springs rising in it. The chief distinctions of the mica-slate from unaltered sandstones or greywackes are the distinct lamination of the component minerals, the frequent aggregation of the quartz in large lenticular masses or nodules, and the contortion or twisting of the beds. This contortion is, however, rarely so violent as in the mica-slate of Loch Goyle and Loch Long, and seldom interferes with the observation of the dip and direction of the beds where a sufficient surface of the rock is exposed.

Associated with the mica-slate, in several localities, beds of limestone are found in considerable abundance. It is usually of a very dark or black colour, highly crystalline, and of a very large coarse grain. It is seen in most abundance in Knock-Scalbert and the other hills north of Campbeltown, where it is quarried in several places. Dr. Macculloch represents the whole of this tract as limestone, but, as the sketch-map will show, it is far less abundant than the igneous rocks, and even than the associated mica-slates*. Some of the beds on the west side of Loch Ruag are more compact and slaty, but still show the same dark colour. Other beds again on the declivity of the hill are a kind of *cipollino*, or rather calcareous mica-slate, consisting of alternate layers of white granular limestone and mica. This limestone series is again seen in the low ridge to the south of Campbeltown

* Perhaps the omission has arisen from the blue used for the trap-rocks being mistaken for that employed for the limestone,—a not uncommon cause of error in other parts of the country.

at the foot of Ben Gollion, near Lime Craigs, and is also quarried on the north side of the Mull district of mica-slate near Achinlisaig.

The dip and direction of a contorted rock, like mica-slate, are necessarily very variable and so far uncertain. In this district they can, however, be determined with considerable accuracy, as the rock is often well exposed in sections. The dip ranges from about 12° or 15° up to 60° or 70°; but on the whole low angles predominate, and an average of seventy observations gives about 30°. The direction of the dip is remarkably uniform, and almost invariably to the east. Thus in seventy-four observations sixty-three were to the eastward, and of these fifty-seven to east by south. The mean direction of the dip is to S. 57° 26′ E. by compass, or allowing 25° for the variation to E. 8° S. (S. 82° E.). In other words, the average direction of the strata is almost identical with the general direction of the peninsula, which is thus merely the outcrop of a system of beds of mica-slate. The same direction is found very constantly as the result of direct observation in the district near the Mull, where the strata have been little intruded on by recent igneous rocks, and it thus appears not merely as the average, but as in reality the original or normal dip of this series of beds. In confirmation of this view, it may be mentioned, that a fourth of the dips observed in the region generally were within 3° of the average deduced, and nearly one half not more than 10° from it. On the north-east side of Ben Gollion, however, a more northerly direction prevails, the strata dipping with few exceptions about 10° north of true east.

The dip of the limestone series, noticed as connected with the mica-slate on the north of Campbeltown, does not coincide with that just deduced, or with that of the mica-slate in the same locality. In eighteen observations, sixteen were to the south-east, one south, and one north-west, and omitting the latter, the mean of the whole gives a dip of 34° to S. 32° E., or, with one doubtful observation omitted, of 32° to S. 30° E. by compass, or S. 55° E. of true direction. This group of rocks, therefore, has a slightly higher dip, and to a point about 25° further south than the mica-slate. This might induce us to believe that the limestone formed a distinct portion of the primary series, but is perhaps owing to the great intrusion on the north of trap-rocks which in this district are almost constantly associated with the limestone*.

The mica-slate forms the general base of the country, on and around which all the other stratified formations have been deposited. The first of these is red sandstone and conglomerate, occurring, as the map (Pl. XXIII.) will show, chiefly on the east and south-east of the district. The relation of these rocks to the inferior formation is most distinctly exhibited in the narrow valley of the Glenramskill Burn, about one mile and a half east of Campbeltown. The west side of this valley is composed of slate, forming the declivity of Ben Gollion, and dipping on an average at 25° to 30° to E.S.E. (S. 75° E.) by compass.

* The same association of igneous rocks with limestone beds is seen in the Silurian rocks of Peeblesshire described by myself, and in those of Ayrshire described by Sir R. Murchison, and is so constant that we can hardly regard it as accidental.

The east side of the glen consists below of mica-slate, followed higher up by a dark red, fine-grained sandstone, on which rest enormous masses of coarse conglomerate, sometimes from 100 to 150 feet thick, and cropping out along the whole escarpment of the mountain. In many places the two formations may be traced within a few feet of each other; but no distinct instance of an actual junction was observed. The nature of the conglomerate, as often happens, rendered it impossible to ascertain its dip with accuracy, and there is so much false-bedding in the sandstones, both those underlying, and those occasionally included in, the conglomerate, that they did not afford much assistance in determining the position of the mass. So far, however, as could be ascertained, there is a remarkable coincidence between the dip of the mica-slate and that of the sandstone resting on it, where both are seen in the closest proximity. The inclination of both masses is to the east or south-east, and occasionally the amount of the dip did not differ above a few degrees, its direction in both rocks being to S. 75° E. by compass. A similar approximation in the position of these formations is seen on the north side of the Bay near Braskomil. In this place the mean of fourteen observations on the inferior mica-slate gave a dip of 41½° to S. 58° E., and of eight observations on the red sandstone, of 49° to S. 63½° E.,—a closer approximation than is found in separate observations on the same rock. The coincidence is also more remarkable from a mass of greenstone, fifty yards wide, having intruded almost at the junction of the two formations, only one bed of mica-slate, hardened and bent over the curved surface of the trap, being seen above it, dipping at 45° to S. 65° E., or within a few degrees of the mean of the sandstone resting on it. In the hill to the north several smaller patches of conglomerate and red shale are seen in a similar approximate parallelism to the mica-slate and limestone in their vicinity.

In examining my notes I was surprised to find a similar coincidence in the dip of these two formations in the extreme south of the peninsula near Keills. The mica-slate, as formerly stated, dips in this place to S. 55° E., and the same direction was found in the red sandstone and conglomerate which abuts on the shore in fine bold sea-worn cliffs near the old grave-yard of Kilcolmkill. A low alluvial tract, however, divides the formations in this place, and I had no opportunity afterwards of examining the locality more closely.

Although these observations are perhaps not sufficient to prove that the red sandstone and conglomerate were deposited conformably on the horizontal mica-slate, they at least show a closer coincidence than I have observed in other parts of Scotland. When we contrast them also with the very marked unconformability of the Devonian red sandstones to the Silurian greywackes in the south of Scotland, they may be regarded as indicating that the elevation of this portion of the crystalline strata is not of very ancient date.

The same conclusion may be drawn from a consideration of the mineral character of these conglomerates, which in other respects also is very remarkable. The materials composing them vary in size from fine sand to rounded blocks frequently of six or eight inches, and not

uncommonly of one, two, or even three feet in diameter. In the conglomerate forming the precipitous coast to the south of Kildalloig, I measured one boulder, still fixed in the rock, 3½ feet long by about 3 feet in breadth and thickness, and several masses of almost equal dimensions, evidently washed out of the rock, were strewed on the beach around. The mineralogical character of the larger pebbles composing these rocks is singularly uniform in each locality. Of eighteen specimens collected at random from one place in Glenramskill Burn, ten were a hard reddish sandstone, two coarser sandstones, and the remaining six reddish brown felspar or claystone porphyries. The conglomerates on the east coast consist almost entirely of reddish brown porphyries, not unlike those of Davar island in the immediate vicinity. Thus fourteen specimens collected in one spot near Kildalloig were entirely of this nature, and only differed in the more or less abundance of light green crystals dispersed through the dark clove-brown basis. In eighteen specimens from another point not far distant, fourteen were also clove-brown porphyries, and four either similar rocks or very hard compact hornstones. In the conglomerates on Knock-Scalbert, north of Campbeltown, the boulders again were chiefly common white quartz, a rock not now seen *in situ* near this place. In the conglomerate west of Southend near Keills, quartz, hardened sandstone, and light-greenish porphyritic traps predominated. In all these cases the conglomerates rest on, or are in the immediate vicinity of, the mica-slate, but I have observed no fragments of it or of other so-called primary strata among their materials. This is the more remarkable, as both the size of the boulders and their uniform character in each locality prove that they have not been drifted from a distance, but are the mere water-worn detritus of a shore consisting of similar rocks. Though the laminar texture of the mica-slate renders it very friable, and mica-slate boulders are consequently far from common constituents of conglomerates, yet this alone will not account for their absence from these deposits. Where this rock now forms the shore, masses of it, of all sizes and in various stages of attrition, abound, and must enter largely into the composition of any boulder deposit now forming. In the Boulder Clay or Drift they are also numerous, and are frequently found fifty miles from their native Highlands, resting on the Silurian strata in the south of Scotland.

The red sandstone connected with these conglomerates, and skirting the east and south coasts of the peninsula, is often a very peculiar rock. It is frequently associated with felspar or claystone porphyries, and is then apparently composed in great part of similar felspathous matter. It then either passes into the porphyries by insensible gradations, or is so intercalated and mixed up with them that the division-line cannot be determined. A section seen near the south-east coast-road, about two and a half miles from Campbeltown, furnishes a good illustration of these gradations. It exhibits a series of thin beds, from 1 to 2 inches each in thickness, of which the upper beds are decided sandstones, whilst the lower approximate more and more to the porphyries. The higher beds are of a reddish brown or yellow colour, somewhat porous, and consist of numerous thin layers

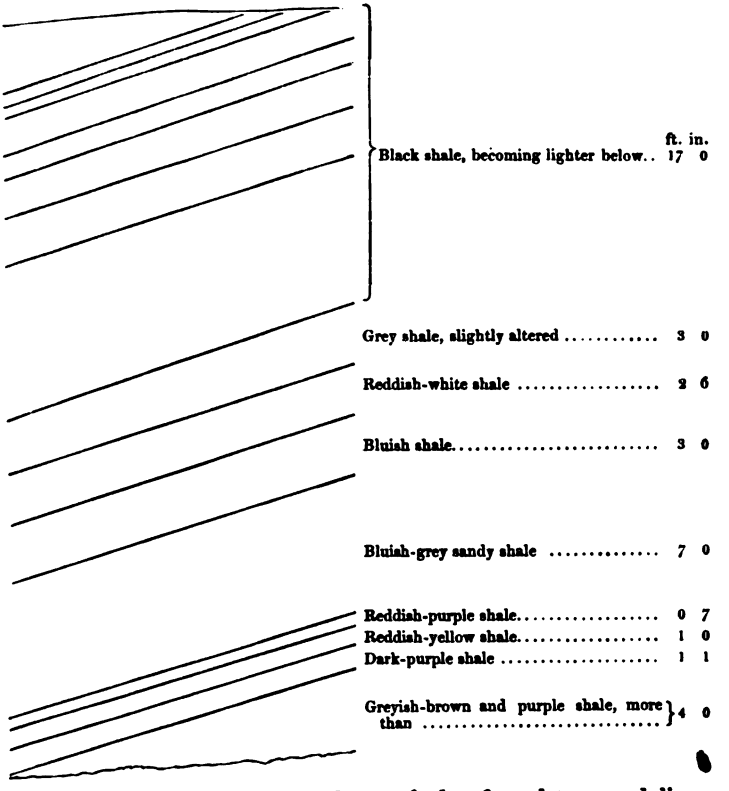
of quartz and felspar grains. The lower beds are more porous, and consist of a brownish red felsite basis, with nodules of a soft white mineral, like Bole. Similar red strata are seen at many points on this side of the peninsula, and often with such a mixture of characters as to render it difficult to decide whether they should be classed with igneous or aqueous formations. Indeed it seems probable that they may so far partake of the nature of both, being in great part composed of the volcanic detritus thrown out during the formation of the felspar porphyries, and thus of the same nature with the "volcanic grits" of Sir R. Murchison, and some of the "ash-beds" of Sir H. De la Beche and the Geological Survey. The want of a good physical map on which to record my observations, and of time to work out detailed sections, renders me still doubtful whether the connection of these beds with the red conglomerates is more than incidental. They may not improbably form a distinct and more recent group.

The next group of strata we shall notice is the Coal-formation, which occurs on the west side of the peninsula near Machrihanish Bay. Coal has been long wrought in the low valley or Laggan west of Campbeltown, but the beds appear to be now nearly exhausted, and the coal generally of inferior quality. The plants found both in the coal itself and in the connected shales, leave no doubt that these beds belong to the true Coal-formation, and not to the Lias as is often said. Fine specimens of the *Stigmaria ficoides* are common not only in the shales but in the coal itself, some beds of which seem chiefly formed of this plant and of a species of *Calamites*. *Lepidodendra* abound in the shales and sandstones, along with *Lepidostrobi*. The only Fern seems a *Pecopteris*, but in general only the stalks are left without any of the leaflets attached. Branches of *Stigmaria*, slightly compressed, and filled, in some instances, with iron-pyrites, in others, with a conglomerate of coarse grains of quartz in a basis of iron-pyrites, also occur in the coal. In some of the sandstones in Tirfergus Burn grass-like impressions and fragments of small stems occur, but too imperfect for the determination of their true characters.

The best section of the carboniferous strata is exhibited in the banks of the stream just named, which runs as it were in a kind of notch cut in the declivity of the hills forming the south side of the Laggan. The stream rises in the trap forming the hills towards Losset. In descending the ravine, the first strata observed are some coarse red conglomerates, consisting chiefly of trap-boulders. On these rest deep red ochrey shales, all dipping east down the stream. After a short interval, in which the rocks are concealed by herbage, deep red shales, apparently the continuation of the former beds, form the bank of the stream. The section is again concealed for some yards by grass, but is resumed by a mass, about 40 feet thick, of shales, purplish or greyish brown below, and passing upwards through bluish grey and reddish white beds, into deep black shale above (see fig. 1). These gradual changes of colour in the strata as we recede from the igneous rock mark in a very beautiful manner the gradual diminution of its metamorphic influence as the

distance from it increases. The change even in the deepest beds is not very great, having apparently only driven off the carbonaceous matter from the black shales, and modified the state of oxidation of the iron in the ferruginous red beds below, which are at the same time somewhat hardened and converted into a kind of porcellanite, yet the heat seems to have extended through from 20 to 30 feet of conglomerate and probably twice that thickness of shales. Further down the stream the same black friable shales are seen in cliffs sometimes 60 feet or more high. They are intermixed with beds of sandstone and impure coal, which has been mined in several places. In the shales I only observed a few obscure indications of fossils.

Fig. 1.—*Section in Tirfergus Burn.*


ft. in.
Black shale, becoming lighter below.. 17 0
Grey shale, slightly altered 3 0
Reddish-white shale 2 6
Bluish shale..... 3 0
Bluish-grey sandy shale 7 0
Reddish-purple shale..... 0 7
Reddish-yellow shale..... 1 0
Dark-purple shale 1 1
Greyish-brown and purple shale, more than 4 0

On the west coast south of Losset, beds of sandstone and limestone, much altered by intrusive igneous rocks, are seen in the high cliffs. Similar altered masses occur near Killellan and in other portions of the tract laid down on the map as trap. Before noticing these, we must describe the igneous rocks seen in this district with which they are intimately connected.

In his Geological Map of Scotland Dr. Macculloch lays down a band of igneous rock as extending continuously from the bay east of Campbeltown to the west coast between Losset and Machrihanish. This band has no existence in reality, the porphyry quarried to the east of the town being soon interrupted by the slate and limestones, and igneous rocks only again appear near Kilkivan, about four miles distant. On the other hand, a large portion of the southern district, coloured by him as mica-slate, is a nearly continuous mass of igneous rocks, intermixed with or overlying secondary strata. In the district north of Campbeltown Loch a large outburst of igneous rocks has also taken place, of which no trace appears in his map. The most abundant igneous rocks are varieties of felspar and claystone porphyries, and then several kinds of greenstone. Of the former the porphyries of Davar island, formerly described by Dr. Macculloch, are the most remarkable, and fully merit the praise he has bestowed on them. The most common have a clove-brown felspar basis, with imbedded crystals of labradorite. In others the basis shows purplish tints with disseminated light green crystals, and others again have a green basis with clove-brown crystals. The stone is always crystalline and of a very firm, uniform texture, and seems admirably fitted for ornamental works, whilst the island would furnish an inexhaustible supply with the most ready means of transport. This mass of porphyry rises up in an isolated position from the sea, and there is thus no means of determining its age; but many of the boulders in the red conglomerate closely resemble this rock, and, if derived from it, would carry its origin back to a very remote epoch.

The porphyries on the mainland are generally far less hard and crystalline than those of Davar island. The chief exception is a mass of porphyry or syenite seen on the road to the Light-house in the slates of the Mull district. This is a very hard rock with a basis of flesh-red orthoclase, in which are disseminated a considerable amount of a greenish white mineral, perhaps oligoclase, but much decomposed in the specimens I brought away, then dark green hornblende in minute crystals, and grains of quartz. The other porphyries are often claystones or compact felsites, like those of the Braid Hills or Pentlands near Edinburgh, and some of them even mere granular tufas, almost like sandstones.

As these rocks intrude on the coal-formation, they cannot be older than its deposition, and not improbably are much newer. One of them, of a reddish yellow colour, quarried near Kilkivan, contains angular fragments of shale converted into a kind of jasper, but still retaining all the laminar texture of the original rock. One of these altered fragments consisted of almost innumerable layers of shale, not much thicker than paper, but readily distinguished by their differences of colour or tint.

The other igneous rocks are augitic traps, partly greenstones or dolerites, partly compact or basalts. One of the most remarkable of them is a basaltic breccia which forms the summit of Knock-Scalbert, immediately north of Campbeltown. It consists entirely of angular fragments, generally not larger than a common marble, but all loosely

reagglutinated into one mass. The rock is one of the most singular breccias I have ever seen, and appeared as if the dome of basalt had been shivered by a violent blow into innumerable fragments and then again subjected to heat until these fragments partially adhered. Some other examples of these formations will be subsequently noticed, and I shall only add, that it is not in all cases possible to separate the felspar series of rocks from those containing augite. They not only occur together, but appear to graduate into each other occasionally.

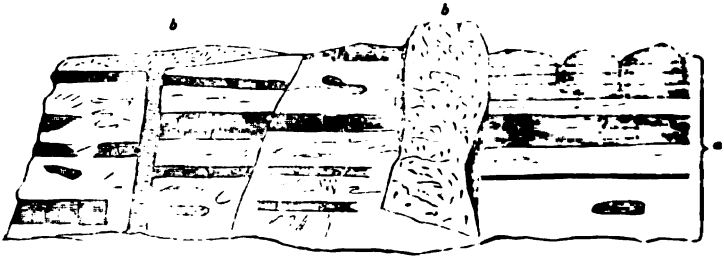
The geographical distribution of these igneous rocks is shown generally by the map, Pl. XXIII. Their relations to the stratified deposits vary considerably in different localities. Those seen in the hills north of Campbeltown partly overlie, partly are intercalated among, the limestone and slate rocks, and partly intersect them in veins. The igneous formation in the south of the peninsula also occasionally overlies or intersects the slates in beds or veins. More often, however, it is connected with the red sandstones and carboniferous strata of that district, which appear imbedded, as it were, among the igneous rocks, in fragments the form and position of which I had not the means of working out in detail.

Some of the sections of these rocks are very interesting. One of the most remarkable is exposed in the cliffs on the west coast about a mile south of Losset. In this place a large outburst of igneous rocks, sometimes amygdaloidal greenstones, at other times grey friable tufas, full of veins of fibrous calc-spar or pure crystallized quartz, overlies beds of reddish clay, resting on limestone, and this on sandstone. The sandstone near the igneous rock is much hardened; the limestone, of a greyish white colour, is nodular, concretionary, of a saccharoid texture, and interlaminated with veins of calc-spar and steatite.

A little further south, the manner in which the trap has found its way to the surface is very beautifully shown. The shore, where laid bare by the waves, between high and low water-mark, consists of beds of highly contorted mica-slate, dipping about 35° to S. 45° E. Higher up, on the old elevated sea-beach, the rocks are concealed by blown sand and the debris from the steep and lofty cliff above. This cliff is formed of sandstone and limestone, which project in thick beds from the turf. In the place represented in the accompanying figure (fig. 2), two veins of trap run nearly vertically up the cliff; and are again seen in a horizontal section on the shore intersecting the mica-slate. The smaller vein, on the north, is about 4 feet wide, and is a dark greenstone, divided into horizontal columns in the centre, but with vertical laminæ on the sides. In the sandstone its course is nearly straight, but in the mica-slate it is very tortuous and irregular, the contortions in the slate having probably caused the fissure to assume a very rugged form. The larger vein is about 40 feet wide, and is a grey porphyritic amygdaloid. In passing through the mica-slate these veins do not seem to alter its usual characters, but merely to fill a fissure in it. The smaller vein appears to spread out in a

tabular mass above, whilst the larger vein terminates abruptly in a rounded knoll.

Fig. 2.—*Trap-veins in the Cliffs near Losset.*



a. Sandstone and limestone. *b*, *b*. Trap-veins.

Further north similar veins traverse the massive or bedded trap, and often project from its surface like rude walls. They are well exhibited on many parts of the terrace or raised beach, having apparently resisted the denuding influence of the sea better than the horizontal mass. They are also, I think, often of a harder and more crystalline structure than the latter, from which they must differ in point of age.

One of the most interesting exhibitions of the trap-rocks occurs on the east coast, near the ruins of Kilhousland church, to the north of Campbeltown harbour. In this place a vein of dark ferruginous greenstone, divided at right angles to the sides into nearly horizontal columns, intersects a mass of light-grey trap which forms the shore for a considerable distance. In some places the latter becomes highly concretionary, and is divided into vertical columns which cover the shore like a miniature Giant's Causeway. These columns are separated from each other by veins of calc-spar, hæmatite, and green earthy carbonate of copper, and the whole rock is in some places impregnated with the latter mineral. The hæmatite is either compact and siliceous, with portions of red hornstone, or it is more granular, with veins and nodules of calc-spar and grains of green earth, or contains druses of calc-spar lined with crystals of quartz. The hæmatite veins are sometimes 3 or 4 inches wide, but generally much less. Occasionally the included column has been entirely removed, when the intercolumnar veins remain like empty honey-combs.

The structure of this singular columnar mass might give rise to many speculations. The usual theory of the formation of basaltic columns is that they have been formed by the contraction of the mass in cooling, and their position, always at right angles to the walls or cooling surface, so far confirms this theory. In general the prisms fit each other very closely, with no wider spaces than the contraction of the mass might be supposed capable of producing. Here, however, we find columns of about a foot in diameter separated by intervals of

from half an inch to 3 or 4 inches, which is far more than mere contraction could produce. It seems, therefore, necessary to suppose, either that the veins of hæmatite were segregated from the rock contemporaneously with the formation of the columnar structure, or that after their formation the prisms were somehow forced asunder, and the vein-matters introduced between them. The latter appears to me the more probable hypothesis of this very curious formation.

The facts just mentioned relative to these igneous rocks show that they not only differ much in mineral character, but also have been formed at very different periods. Some are probably more ancient than the red conglomerate or coal-formation; others are contemporaneous with these beds; others again were produced after their deposition, whilst a fourth group even intersect the latter as veins. Their mode of occurrence also differs very much; some appearing as huge domes or prisms pushed up through the strata; others as overflowing or intercalated beds; and others as veins or dykes filling cracks or fissures in the older formations both stratified and igneous.

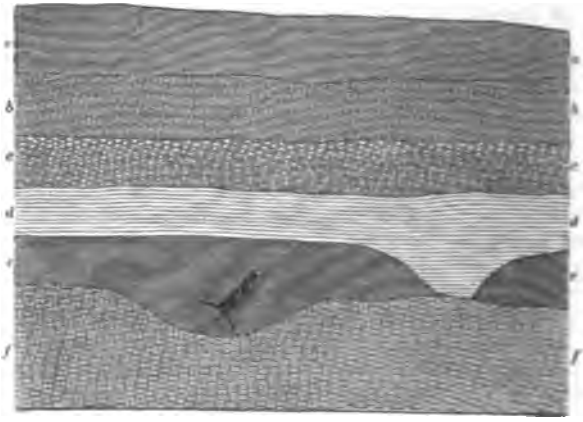
In Dr. Macculloch's map of Scotland, part of the valley west of Campbeltown is coloured as Lias, and the same formation is marked as occurring in this locality in most of the recent geological maps of the British Islands. After a careful examination of the district, I have not been able to find any indications of the Lias formation. The plants in the coal-beds now wrought are, as formerly noticed, only those of the true Coal-formation, and no trace of lias fossils was observed either in the rocks themselves or in the detritus of the country. In the sandstones and limestones connected with the trap-rocks organic remains appear to be wanting, but the general character of the beds and their relation to the undoubted carboniferous strata, left no doubt in my mind that they were portions of this rather than of any more recent group of rocks. It thus appears, that the Lias must be obliterated from this portion of the geological map of Scotland. How it ever came to be introduced is not readily explained. In his 'Mineralogical Travels,' Professor Jameson describes the beds as belonging to the Coal-formation. In his work on the Western Isles*, Dr. Macculloch says that the coal wrought near Campbeltown is a portion of that of Ayrshire. In the same place, however, he identifies it also with the coal underlying the trap in Mull and Morven, and when the latter was proved to belong to the Lias, he probably assumed, without renewed investigation, that this was true in like manner of the coal at Campbeltown.

The tract coloured in Macculloch's map as Lias, together with a part of the red sandstone on the north, is, however, covered to a great depth with recent deposits, partly at least of tertiary age. The country between the Loch of Campbeltown and Machrihanish Bay on the Atlantic is a low broad valley, known as the Laggan of Cantyre, and so little elevated above the sea that a depression of 40 feet or less would convert the whole southern part of the peninsula into an island. This valley is filled by various unconsolidated deposits. The

* Vol. ii. p. 71.

lowest of these is a mass of red clay, very hard and tenacious, and containing large rounded boulders often grooved and striated. This bed thus corresponds with the great Drift or Boulder Clay deposit in other parts of Scotland. On it rest thick shingle-banks, composed of layers of sand, gravel, and well-rounded stones of various sizes. On these stones no grooves or striæ were seen, but they closely resemble the waterworn stones on the shore of the sea. The boulder clay in some places rises into low hills; the shingle-deposits rather form banks or terraces, of which three or four at different elevations may occasionally be traced. In the hollows between these hills and banks large deposits of peat, associated with fine clays and sands, have been formed. Sections of the upper portions of these formations are often well exposed in the banks of the stream that drains this valley.

Fig. 3.—*Section in the Moss near Backs.*



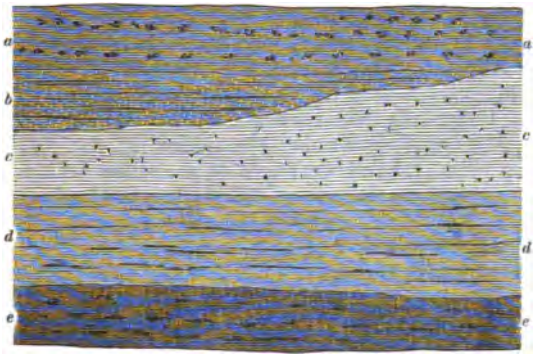
	inches.		inches.
a. Soil	12 to 14	*d*. White clay	8 to 10
b. Brownish-red clay	12	*e*. Peat, with trees	10 — 20
c. Deep red ferruginous clay	12	*f*. Red clay	24 — 36

Fig. 3 is one of these sections, presenting some curious peculiarities. The lowest bed *f* is a red clay, but different in character from the inferior boulder clay. Only from 2 to 3 feet thickness of this was seen, but the bed is probably deeper. On it follows a bed of peat with numerous roots and branches of trees. In some places the roots seemed to have sunk into the red clay, and there the peat was also deeper. On this followed a bed of white clay, in one place entirely cutting off the peat, as shown in the section. Above this was 12 inches of deep red ferruginous clay, then as much of brownish red clay, and the whole covered by about 12 or 14 inches of soil.

The two following sections (figs. 4 & 5), of which the details are subjoined, will show the variations to which these deposits are liable, though some of the beds, as the peat-bed marked *e*, with *d*, *c*, and *b*, seem very constant over a considerable extent of surface. The wood

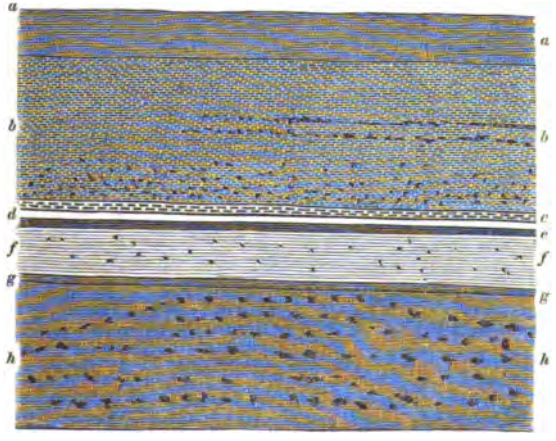
contained in the moss is chiefly birch and oak, and the trees are occasionally of considerable size, one measuring above $2\frac{1}{2}$ feet in diameter.

Fig. 4.—*Section near Dyework two miles west of Campbeltown.*



	inches.		inches.
a. Brown clay with beds of fine gravel ..	14	*d*. Dark bluish brown clay	20
b. Brown clay with no gravel	6	*e*. Lignite bed	12
c. Light brown sandy clay	22		

Fig. 5.—*Section near Bleachfield west of Campbeltown.*



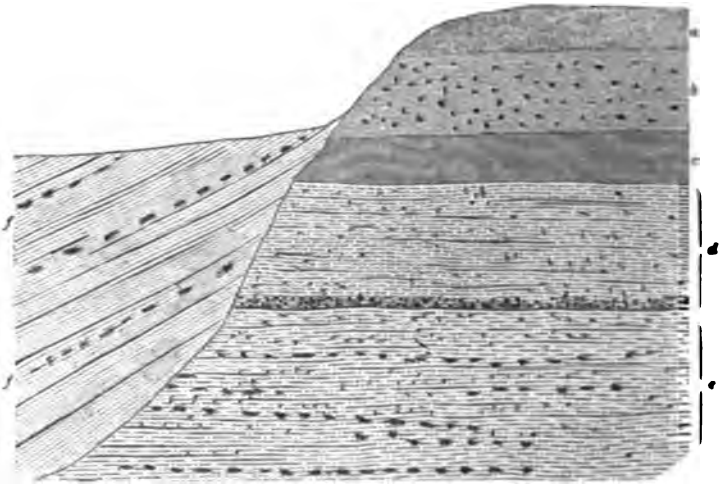
	inches.		inches.
a. Soil	10 to 12	*e*. Lignite bed of clay and plants mixed	2
b. Clay with veins of sand in the middle and more sandy below ..	20	*f*. Sandy clay	10
c. Red ferruginous clay	4	*g*. Peat	2
d. Bluish-white clay	3	*h*. Peaty gravel	more than 30

Besides the trees, leaves, some of them apparently of the common alder, occur in considerable abundance, and hazel-nuts are not uncommon, and, when the river was deepened, these were in some places found in great heaps. I did not observe any shells or animal remains

in these beds. The roots of the trees in the bed *e* are often fixed in the red clay below, in which they appear to have grown. The upper beds exhibit more of a lacustrine or fluviatile character, and near the high grounds become more arenaceous and gravelly than in the central parts of the valley. They thus indicate the margin of the ancient lake in which these strata were probably deposited. The whole formation reminded me of the freshwater and lignite beds on the north-east coast of Norfolk, formerly described by Sir Charles Lyell, and may probably be regarded as of nearly the same age. It is evidently more recent than the red Boulder Clay or Till, but also clearly older than the great peat-bed now forming the surface of the district. The upper beds were probably deposited in a shallow lake which may have been drained by the river cutting down the bank of sand and gravel by which the water was retained, in consequence of its increased action when the land was raised.

The section fig. 6, seen in the bank of the small river near Ma-

Fig. 6.—*Section near the mouth of the Machrihanish River.*



	inches.		inches.
a. Soil and blown sand.....	10 to 12	*d*. Brown arenaceous clay.....	30
b. Round water-worn gravel	18	*e*. Sandy clays with layers of gravel	36 to 48
c. Peaty soil with remains of plants	10	*f*. Beds of sand and gravel	

chrihanish, exhibits the relation of these older and lacustrine beds to the blown sand and more recent deposits on the coast. The whole shore of the bay is occupied by hills of blown sand, covered by scanty herbage. In this place these blown sands are seen resting unconformably against the ends of the more ancient beds, and, what is curious enough, the newer beds are inclined at a considerable angle, whilst the older follow[illegible]es are nearly horizontal.

That [illegible]ed, will show [illegible]of the Firth of Clyde have recently been elevated about [illegible] some of the [illegible] the former level of the sea is now so well known, seem very constant o[illegible]

that I should hardly have thought of noticing the fact had it not been for some other connected points. One of these is the long period during which the land appears to have remained stationary at its former level. All round the Mull of Cantyre the ancient sea-line is marked by lofty precipitous cliffs, hollowed out in many places into deep caves. Even where they occur in the red sandstones, limestones, or softer trap-rocks, these sea-worn caves are well calculated to excite surprise. But this is far more the case where they have been excavated in a hard rock like the porphyries of Davar Island. The effects of sea-action on this isolated rock are exceedingly interesting. On the north-west side, which is turned to the land or mouth of the harbour, the island slopes gradually to the sea-level, and the ancient beach is scarcely marked by a slight notch or indentation. On the eastern side, turned to the open Firth, it is surrounded by high bold cliffs of rudely prismatic porphyry. Below this vertical wall, a horizontal ledge of rock extends outwards for fifty yards or more, and is covered in most places at high water, but is dry at ebb tide. This ledge also terminates abruptly in another vertical wall, the water, on one occasion when I visited it, being about four feet below its edge, but still apparently very deep. Its surface is strewed with huge, well-rounded blocks of porphyry, which almost disappear near the outer margin, but become more abundant near the foot of the cliff. Boulders of 12 to 18 inches in diameter are very common, and are usually thoroughly rounded, showing that the waves have no difficulty in moving stones of that size. When from 4 to 6 feet in diameter the blocks are generally more cubical and only the corners worn off, but even then they are evidently yielding to the abrading influences of the sea. On the south-east, or most exposed side of the island, the ledge seems to be rapidly disappearing, and the rounded boulders covering it are fewer than on the northern side where the wave-action is less. In the latter place the ledge is wider, and the blocks form thick heaps, apparently arranged in two or three rows or beaches.

These facts show the present action of the sea obliterating, as it were, the traces of its action in former times. The old and new beaches will sooner or later coincide, and all record of the former be then wholly destroyed. To judge from appearances, the sea must have stood much longer at the higher level than it has at its present elevation. In the wall of rock above this ledge, and quite beyond the action of the waves at the present time, many caves occur. One of these with a double mouth, or rather two caves meeting in the interior, measured 130 feet in length. Its sides and bottom were smooth and worn as if by the beating of the waves, and the heaps of well-rounded stones, covering the floor in many places, showed the tools by which this immense excavation had been chiselled out of the solid rock. Fragments of recent shells were lying on the floor, but probably carried in by men or by the sea-fowl, which, with flocks of wild pigeons, had their nests in crevices of the lofty walls. When the waves beat into this cave, the sea must have been at least 30 feet relatively higher than at present. Even though some fissure in the

rock, or softer vein of stone, may have determined the greater waste in this place, still the time required for its formation must have been enormous. It seems indeed almost impossible to estimate the number of ages spent by the waves in cutting out a cave of 130 feet in length in a rock of such hardness as the porphyries of Davar Island*.

There are other indications of recent geological action in this locality which it is sufficient merely to mention. Many of the striated boulders in the clays are apparently derived from a distance, and some detached travelled stones are seen on the surface. Thus, near Macharioch I observed several large boulders of white granite, one of them measuring 5 feet by 4, and projecting 2 feet from the ground in which it was partially buried. The stone resembles the granite of Arran, which is the nearest place where this rock occurs *in situ*, though at the distance of twenty-five miles across the deep hollow of the Kilbrannan Sound. Striated rocks were noticed in several localities, of which the following were the most distinct:—

Hill above Smerbie, on east coast, on claystone-porphyry. Direction S. 55° E. In the line of a hollow to the sea.

On the south road, east coast, near the third milestone, on claystone-porphyry. Horizontal striæ on a vertical face of rock. Direction S. 55° W.

On the south road, near the sixth milestone, striæ on sandstone newly uncovered. Direction E. 10° N. (by compass). This is nearly parallel to the line of coast, and in the direction of Arran. The north-east faces of the rock seemed the most highly polished.

On the road, about four miles from the Lighthouse, the newly exposed mica-slate was rounded, with indistinct striæ, some running nearly N. and S. along the valley to the sea.

Some results of the examination of this little-visited portion of Scotland appear of considerable interest in connection with the general geology of the country. In regard to the oldest rock, or so-called mica-slate, its most important peculiarities are its arenaceous, slightly metamorphosed character and peculiar mineral composition, on the one hand,—its anomalous direction and constant easterly dip on the other. In a former communication to the Society†, I pointed out the approximate parallelism of the great band of clay-slate and mica-slate along the southern margin of the Grampians to the Silurian

* Besides, we must take into account the portions cut away from the exterior during the formation of the interior cave. The length of this cave marks, not the total wave-action during the period of its formation, but the difference of this action in the interior and on the exterior. The sea-cliff in which these caves occur is no less strongly marked on the opposite shore of the Firth of Clyde, in the Silurian rocks described by Sir R. Murchison. It is there also perforated by caves, or cut by open fissures of enormous size, marking the long period during which the sea remained at this level. It is remarkable, that, although several supposed higher beach-lines have been pointed out, none of them exhibit either the continuous line of cliff, or the numerous sea-worn caves of this 30-feet beach. It evidently marks a period of longer pause in the upward motion of the land than any former line—a pause also longer than the present has yet been.

† Quart. Journ. Geol. Soc. vol. vi. p. 53 *et seq.*

strata in the south of Scotland; and expressed my belief that these two formations were the two sides of a great synclinal trough in which the coal-formation was deposited. The facts above-noticed seem to add confirmation to this view. In mineral character the beds are intermediate between the Silurian slates and greywackes in the south, and the crystalline strata on the north. The position of the beds corresponds to this view. The peninsula of Cantyre is as it were the outcrop of the western extremity of the long trough-like basin of central Scotland. I have not examined the upper part of the peninsula between Skipness and Loch Tarbert, but have little doubt, from its physical geography, that the strata there will be found curving gradually round into the normal E.N.E. direction of the central Highlands. The clay-slate in Arran shows the same curve, but thrown off much further to the east by the intrusion of the granite of Goatfell, which, however, took place at a more recent period, or after the deposition of the carboniferous strata*. In confirmation of the identity of the crystalline strata in the north with the Silurian rocks of the south, we may mention the illustrative fact that calcareous matter pevails most extensively towards the western extremity of both groups of rocks. In the Silurian strata at their eastern termination near St. Abb's Head, no calcareous beds are known; they begin to appear in thin courses in Peeblesshire near the centre of the chain, and are very abundant in Ayrshire. It is the same with the crystalline strata. In the coast-section from Stonehaven to Aberdeen, I have seen no calcareous bands; in Forfarshire and Perthshire several are known; they become still more abundant in the north of Argyllshire; and in Cantyre we have, as just stated, a great group of limestone rocks.

If this analogy be sustained, it follows that the upheaval of these strata has taken place soon after the deposition of the Lower Silurian series, and that no new strata have been formed until near the close of the Devonian or commencement of the Carboniferous epoch. In this place, at all events, the upper old red sandstone and coal-formation rest immediately on a mica-slate, which I conceive to be of Lower Silurian age, the whole of the Upper Silurian and Lower Devonian being omitted. The same order seems to prevail in the north and west of Ireland, where, in some places, the red conglomerates and coal-measures follow immediately on the mica-slate, in others on the Middle or Lower Silurians. Hence the great break in the continuity of the Scottish formations is between the Lower Silurian strata on the one hand, and the Old Red Sandstone on the other†.

I formerly pointed out the predominance in the mountain-chains of Scotland of two great lines of elevation, the one running from W.S.W. to E.N.E., predominating in all the eastern and central portions of the kingdom; the other with a S.W. to N.E., or even more

* See Sedgwick and Murchison on the Geology of Arran, Trans. Geol. Soc. 2nd ser. vol. iii. p. 21.

† This may explain why Scottish geologists generally placed the division-line between the Transition (=Silurian) formations and the Secondary before the Old Red Sandstone, and not subsequent to it as in other countries.

north and south direction, predominating on the west coast*. I also referred the origin of the former line to the outburst of the older granites; of the latter rather to the newer porphyries and traps. Subsequent observations have greatly confirmed these views, and impressed me with the conviction that the most marked features in the physical geography of Scotland may be referred to the great W.S.W. and E.N.E. line of elevation on the one hand, and on the other to a second great line of upheaval running nearly north and south along the west coast, and passing as it were into the first line in the remarkable fissure of the Great Glen.

Though the crystalline strata on the southern margin of the Highlands are thus identified with the clay-slates and greywackes of the southern Silurian rocks, I would not extend this view to the great gneiss formation (including much quartz rock) which covers about one-third of the whole surface of Scotland. I have not yet had sufficient opportunities of examining the relations of this rock to the granite and mica-slates with special reference to the question, to speak with confidence on the matter. Be this as it may, it seems evident that we need look for no lower group of fossiliferous strata below the Silurian in this part of the kingdom. If these have been converted into crystalline clay-slates and mica-slates, any lower group of rocks must have been much more highly metamorphosed, and all trace of organization—if such ever existed in them—wholly obliterated.

The red sandstones and coal-measures show a connection on the one hand with the rocks of the same age in the central district of Scotland, and also with the small deposit of coal formerly wrought near the Fair Head on the opposite coast of Ireland, which also rests immediately on crystalline strata. We have here the western termination of the great gulf or basin in which the carboniferous strata of Scotland were deposited. The outlines of the margin of this carboniferous basin may thus be pretty accurately traced out on the west, whilst on the eastern side it probably opened into the great sea on whose shores or gulfs the coal of the north of England was deposited. This definition of the margin of the carboniferous sea may so far compensate for the erasure of the lias from this part of Scotland, where it seemed to form a valuable connecting link between the mesozoic Irish strata and those of the Hebrides.

The changes now introduced into the geological map of Cantyre show that its structure bears the closest analogy to that of the neighbouring island of Arran. In both localities there is a nucleus or basis of old crystalline strata, on or around which a deposit of red sandstone and coal has taken place, all of them again broken through, altered, and overlaid by igneous rocks,—predominantly felspar and claystone porphyries. Both districts have subsequently been invaded by innumerable veins of augitic trap-rocks; these veins are seldom of great width, but often continuous in nearly straight lines for long distances. In the lower red sandstones of both regions conglomerates also prevail. The absence of primary boulders in the conglomerates of Cantyre recalls the fact, noticed by Sir R. Murchison and

* Geology of Scotland, p. 11-16.

Professor Sedgwick, of the want of granite boulders in those of Arran. Both rocks also abound in water-worn fragments of hard sandstones, thus evidently belonging to some more ancient formation, though of what age and where existing cannot now be determined. The date of some portions of the red sandstones both in Arran and Cantyre is very uncertain from the entire want of fossils. The distinguished geologists just named, though now of a different opinion, and regarding it as carboniferous, at one time considered the sandstone in the south of Arran as the New Red Sandstone, whereas Dr. Macculloch coloured the whole as Old Red, identical with that below the coal on the opposite coast of Ayrshire. This is no doubt the true age of a portion of that in Cantyre, though other parts, mentioned above as probably contemporaneous with the felspar-porphyries, would in that case be of newer date, and even posterior to the coal. In the absence of organic remains, it is, however, impossible to determine their precise age, or their relation to the strata of other countries.

The introduction of the large overlying mass of trap is the most important change I have been able to make in the geological map of this portion of Scotland. It has long been known that an almost continuous band of igneous rocks traverses the country from the German Ocean near Montrose to the island of Arran. Here formerly it might have been supposed to terminate, the fragments laid down by Macculloch near Campbeltown being comparatively inconsiderable. Now, however, they are found to appear in full force in the southern part of Cantyre, thus traversing the entire breadth of Scotland, and connecting the trap-rocks of that country with those in the north of Ireland. The age of the trap-rocks associated with the Scottish coal-field is very uncertain, there being no more recent formations with which their outburst can be compared. Could we regard the igneous rocks in the north of Ireland as the true continuation of this band, its origin at a far more recent period than is usually supposed would be so far rendered probable. The direction of this band is approximately parallel to the southern Silurian rocks and the northern mica-slates and clay-slates. This coincidence of the lines of more recent igneous eruptions with lines of ancient upheaval and fracture has been repeatedly observed, although, perhaps, rarely on such an extensive scale. The length of this band even in Scotland alone is above 150 miles in a straight line.

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9. *Comparison of the* Devonian Series *of* Belgium *and* England. By D. Sharpe, Esq., F.R.S., G.S.

[This paper was withdrawn by the Author, with the permission of the Council.]

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10. *On the Meaning of the term* "SILURIAN SYSTEM," *as adopted by Geologists in various countries during the last ten years.* By Sir R. I. MURCHISON, F.R.S., G.S. &c.

[This paper was printed in No. 31. p. 173.]

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11. *On* AIR-BUBBLE MARKS, *whether they are distinguishable from* RAIN-MARKS. By M. ED. DESOR.

[This paper was withdrawn by permission of the Council.]

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12. *On the Sections of the* LOWER LIAS *at* MICKLETON TUNNEL *and* ASTON. By G. E. GAVEY, Esq., F.G.S.

[The publication of this paper is deferred.]

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13. *On* FOOT-TRACKS *found in the* NEW RED SANDSTONE *at* LYMM, CHESHIRE. By ROBERT RAWLINSON, Esq.

[Communicated by the Right Hon. the Earl of Ellesmere, F.G.S.]

[The publication of this paper is deferred.]

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY,

April 1st, 1852, to June 30th, 1852.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

American Journal of Science. Vol. xiii. no. 39.

Architect Journal, May.

Assurance Magazine. Nos. 5 and 7. *From the Institute of Actuaries.*

Athenæum Journal, March, April, and May.

Berwickshire Naturalists' Club, Proceedings. Vol. iii. no. 2.

Bordeaux, Société Linnéenne de, Actes. Tome xvii. liv. 6.

Cambridge Philosophical Society, Transactions. Vol. ix. part 2.

Chemical Society, Quarterly Journal. No. 17.

France, Société Géologique de la, Bulletin. Deux. Série, tome ix. f. 5–10.

Horticultural Society, Journal. Vol. vii. part 2.

Indian Archipelago, Journal. Vol. v. nos. 11 and 12; and vol. vi. nos. 1 and 2. *From J. R. Logan, Esq., F.G.S.*

London, Edinburgh, and Dublin Philosophical Magazine, April, May, June. *From R. Taylor, Esq., F.G.S.*

Paris, l'Académie des Sciences de, Comptes Rendus. Prem. Sem. tome xxxiv. nos. 8–22.

————, Mémoires présentés par divers savants. Tome xiii.

————, l'École des Mines, Annales. Quatrième Série, tome xix. liv. 1–3, and tome xx. liv. 4 and 5.

Paris, Muséum d'Histoire Naturelle de, Archives. Tome v. liv. 4, and tome vi. liv. 1 and 2.

————, Catalogue Méthodique de la Collection des Mammifères. Liv. 1.

————, Catalogue Méthodique de la Collection des Reptiles. Liv. 2.

Philadelphia Academy of Natural Sciences, Journal. Vol. ii. part 2.

————, Proceedings. Vol. v. nos. 11 and 12.

Puy, Société d'Agriculture, Sciences, Arts et Commerce du, Annales. Tome xv. Prem. Sem. 1850.

Royal Cornwall Polytechnic Society. 19th Annual Report, 1851.

Royal Society, Proceedings. Vol. vi. no. 87.

Scarborough Philosophical Society. 20th Report, 1851.

Vienna, Imperial Academy of, Transactions. Vol. iii. part 1.

————, Bulletin, 1851. Vol. vii. nos. 3, 4, and 5.

Woolhope Naturalists' Field Club, Rules, 1852. *From Sir R. I. Murchison, F.G.S.*

Zoological Society, Transactions. Vol. iv. part 2.

II. GEOLOGICAL AND MISCELLANEOUS BOOKS.

Names of Donors in Italics.

Athenæum Club, Annual Report of the. 1852.

Carter, H. J. Memoir on the Geology of the S.E. Coast of Arabia.

Davidson, T. A Monograph of British Tertiary Brachiopoda. Part 1.

————. Notes and Descriptions of a few Brachiopoda.

————. Sketch of a Classification of recent Brachiopoda.

Delesse, A. Mémoires sur la composition et constitution minéralogique des Roches des Vosges.

————. Recherches sur l'association des Minéraux dans les Roches qui ont un pouvoir magnétique élevé.

D'Orbigny, A. Paléontologie Française. Terrains Jurassiques, liv. 71–74; Terrains Crétacés, liv. 177–184. *From J. C. Moore, Esq., Sec. G.S.*

Ehrlich, Carl. Geognostische Wanderungen im Gebiete der nordöstlichen Alpen. Ein special Beitrag zur Kenntniss Oberösterreich's.

————. Ueber die nordöstlichen Alpen. Ein Beitrag zur näheren Kenntniss des Gebietes von Oesterreich.

Gasc, F. Education in England.

———. Free Trade in Colonization.

———. Revolutions in France.

Haidinger, W. Berichte über die Mittheilungen von Freunden der Naturwissenschaften in Wien. Vol. vii.

———. Naturwissenschaftliche Abhandlungen. Vol. iv.

Haughton, Rev. S. On the Original and Actual Fluidity of the Earth and Planets.

Hausmann, J. F. L. Ein Blick auf die äussere Geschichte der Königlichen Gesellschaft der Wissenschaften zu Göttingen.

Murchison, Sir R. I. Additional Remarks on the Deposit of Œningen in Switzerland.

———. Geology of the Alps, Apennines, and Carpathians. (Abstract).

———. On the Distribution of the Superficial Detritus of the Alps.

———, and Prof. Naumann. On the Permian System in Saxony.

———. On the Silurian Rocks of Dalecarlia.

———. On the Silurian Rocks of North Wales.

Observations made at the Magnetical and Meteorological Observatory at Bombay, for 1847. Part 2. Meteorological Observations. *From the Directors of the Hon. East India Company.*

Observations made at the Magnetical and Meteorological Observatory at Hobarton, vol. ii. *From Col. Sabine, by direction of the British Government.*

Pictet, F. J. and *W. Roux.* Description des Mollusques fossiles qui se trouvent dans les grès verts des environs de Genève. Liv. 3.

Pole, W. Water Supply of London.

Reports on the Gold Districts of Australia. *From Capt. P. King, R.N.*

Sismonda, Eugenio. Osteografia di un Mastodonte angustidente.

Smith, The Rev. J. Pye. The Relation between the Holy Scriptures and some parts of Geological Science. 5th Edit. With a short sketch of the Life of the Author. *From the Editor, the Rev. J. H. Davies, B.A.*

Sorby, H. C. On the Microscopical Structure of the Calcareous Grit of the Yorkshire Coast.

———. On the Contorted Stratification of the Drift of the Coast of Yorkshire.

Trimmer, J. On the Agricultural Geology of England and Wales.

———. On the Diluvial or Northern Drift of the Cambrian Chain.

Trimmer, J. On the Geology of Norfolk.

Walchner, Fr. Darstellung der geologischen Verhaltnisse des Mainzer Tertiärbeckens und seiner fossilen Flora und Fauna. *From Sir R. I. Murchison, F.G.S.*

————. Darstellung der geologischen Verhaltnisse des Süsswasser-Mergels von Oeningen und seiner fossilen Flora und Fauna. *From Sir R. I. Murchison, F.G.S.*

GEOLOGICAL SOCIETY OF LONDON.

ANNUAL GENERAL MEETING, FEB. 20, 1852.

REPORT OF THE COUNCIL.

THE Council of the Geological Society beg to lay before the Meeting their Annual Statement of the principal occurrences of the past year. Although in number the Society has sustained a slight loss from deaths and resignations, still the satisfactory state of the Society's finances, and the increasing demand for their publications, entitle the Council to congratulate the Meeting on the general prosperity of their affairs. During the past year the Society has lost 21 Fellows by deaths, and 8 by resignations, in all 29. Thirteen new Fellows have been elected, and one elected in the previous year has paid his admission-fee in the past year, in all 14. Deducting this number from the 29 mentioned above, the total loss of Ordinary Fellows is 15. The Society has lost 1 Foreign Member by death, while 5 new Foreign Members have been elected, thus reducing the total loss to 11: the total number of the Society in 1851 was 875, and in the present year 864.

The income during the past year has exceeded the expenditure by £47 11*s.* 9*d.*; and during the last four years, the total excess of income over expenditure is £216 1*s.* 11*d.*

The number of compounders at the close of 1850 was 132, and at the close of 1851 it was 133; 4 compounders having died and 5 Fellows having compounded within the year, three of whose compositions have been vested in the Funds. The total amount received from these 133 compounders has been £4189 10*s.* The amount of Stock held by the Society at the close of 1850 was £3695 3*s.* 5*d.*, and at the close of 1851 £3792 3*s.* 11*d.*; the estimated value of which (taking Consols at 95) is £3600, while two compositions still remain to be funded in the course of this year.

The Council have to announce the completion of Vol. VII. of the Quarterly Journal, and the publication of the first Part of Vol. VIII.

During the past year, Mr. Lumley, the Bookseller in Southampton Street, proposed to the Council to purchase the stock of unsold Transactions in the Society's possession. The Council, after anxious consideration, came to the conclusion, that the best mode of putting these works in circulation, and thereby diffusing a taste for geological research, was to dispose of them to a bookseller of reputation. They accordingly concluded an agreement with Mr. Lumley, under which they made over to him, for the sum of £100, all their stock of Transactions, with the exception of 50 copies, which the Society retains for its own purposes. It was stipulated that the copper-plates should continue to be the property of the Society, and that Mr. Lumley should have the use of them for completing his own sets. The Council at the same time ordered that of the 50 copies retained by the Society, 25 shall be sold to Fellows at the former reduced price.

The Council have taken into consideration the collection of Geological and general Maps in the Society's possession, with a view to render them more available than their present state admits of. The greater part of the maps are not mounted, and therefore cannot be consulted conveniently, or without risk of injury; and thus a very valuable collection is less noticed than it deserves. They have accordingly ordered that the Maps and Sections of the Geological Survey, presented by the Board of Ordnance, together with such other geological maps as may seem deserving of care, shall be mounted and kept in cases. They have further resolved, that Fellows shall have the privilege of borrowing maps or sections when mounted, upon making application to the officers; it being understood that the maps are not to be used for field-purposes in geological excursions. The Council in granting this privilege think it advisable to couple it with this restriction, in which, as it is for the benefit of all, they trust the Society will acquiesce.

The Society has long felt the want of good geological maps of Scotland and of Ireland on a large scale. The forthcoming map of Ireland by Mr. Griffiths will soon, it is hoped, supply one of these deficiencies: for the other, the Council have purchased Lewis's Map of Scotland, and have requested Mr. Greenough and Mr. Sharpe to colour it geologically; which task those gentlemen have kindly undertaken.

In conclusion, they have to inform the Society, that they have awarded the Wollaston Palladium Medal for this year to William Henry Fitton, M.D., F.R.S. and G.S., for his many valuable and original contributions to geological science; more especially for his excellent and elaborate Memoir "On the relations of the Beds between the Chalk and the Purbeck Limestones in the S.E. of England," published in the 4th Volume of the Transactions of the Geol. Soc. for 1833; and for "The Stratigraphical account of the Atherfield Section in the Isle of Wight;" published in the Quarterly Journal of the Society for 1847. The Council have also awarded the balance of the

proceeds of the Wollaston Donation Fund, to John Morris, Esq., F.G.S., to aid him in the publication of the 2nd edition of his valuable "Catalogue of British Fossils."

Report of the Museum and Library Committee.

Museum.

In the British Collection, many specimens received during the year have been placed in the drawers by Mr. Jones, which have made it necessary for him to arrange afresh the collections from the London Clay, Wealden, and Kimmeridge Clay Formations, in which Mr. Morris has been kind enough to assist. The specimens above referred to include the beautiful series from the London Clay presented by Mr. Charlesworth. The valuable collection of Fish-remains, from the Mountain Limestone, presented by Capt. Jones, has also been arranged in good order.

The larger specimens (not in drawers) have been re-labelled and arranged in groups. The same has been done to such of the large specimens exhibited on the staircase as required it.

In the Foreign Museum, the Fossils from the Cape of Good Hope have been put in excellent order by Mr. Jones; who has also re-labelled and arranged the large specimens at the top of the cases as far as the space permitted. There are some valuable specimens in this museum too large to be placed in drawers, and for which there is now no place provided; the Committee recommend that four shelves be added to the glazed recess on the second landing-place, for the purpose of receiving them.

Mr. Pratt has drawn up a Catalogue of the geographical collections of Foreign Rock-specimens, which will enable these to be consulted with convenience.

Mr. Pratt has undertaken to examine and put in order the collection of simple minerals in the Library, and has already worked into their places most of the additions to this department, and arranged more than half of the collection.

Library.

Considerable additions of new books and of books lately bound having been made lately, a number of volumes have been removed into the Council Room, including early editions and works seldom referred to. This has made it necessary to re-arrange the books on most of the shelves, and to alter the press-marks in the catalogue, as well as to re-label most of the books; all of which work is now complete.

The book-case ordered by the Council has been placed in the Assistant Secretary's room, and will contain all the additions likely to come in for some time.

The Committee feel it unnecessary to mention what has been done in the Map-department, as that will of course be explained by the gentlemen to whom that matter has been referred.

Signed, DANIEL SHARPE.
S. P. PRATT.

Somerset House, 17th January, 1852.

Comparative Statement of the Number of the Society at the close of the years 1850 *and* 1851.

	Dec. 31, 1850.		Dec. 31, 1851.
Compounders	132		133
Residents	215		207
Non-residents	461		453
	808		793
Honorary Members	17		17
Foreign Members	46		50
Personages of Royal Blood	4—67		4—71
	875		864

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years 1850 *and* 1851.

Number of Compounders, Residents, and Non-residents, December 31, 1850			808
Add, Fellow elected during former years, and paid in 1851	Resident	1	
		— 1	
Fellows elected, and paid, during 1851	Residents	8	
	Non-residents	5	
		—13	
		— 14	
			822
Deduct, Compounders deceased		4	
Residents		6	
Non-residents		11	
Resigned		8	
		— 29	
Total number of Fellows, 31st Dec. 1851, as above			793
Number of Honorary Members, Foreign Members, and Personages of Royal Blood, December 31, 1850			67
Add, Foreign Members elected in 1851			5
			72
Deduct, Foreign Member deceased			1
		As above	71

Number of Fellows liable to Annual Contribution at the close of 1851, *with the Alterations during the year.*

Number at the close of 1850		215
Add, Elected in former years and paid in 1851		1
Elected and paid in 1851		8
Non-residents who became Resident		7
		231
Deduct, Deceased	6	
Resigned	8	
Compounded	4	
Became Non-resident	6	
	—	24
	As above	207

Deceased Fellows.

Compounders (4).

James E. Bicheno, Esq.
John Fisher, Esq.
Lord Langdale.
L. H. Petit, Esq.

Residents (6).

Viscount Alford.
Thomas Harrison, Esq.
Marquis of Northampton.
Joshua Milne, Esq.
Major-Gen. Sir W. Morison.
Col. Edgar Wyatt.

Non-residents (11).

Rev. John Brown.
Sir J. M'Pherson Grant, Bart.
Prof. John Kidd, M.D.
Rev. William Kirby.
Richard Phillips, Esq.
Lieut.-Col. Alexander Robe.
Rev. J. Pye Smith, D.D.
Capt. Owen Stanley, R.N.
R. C. Taylor, Esq.
Benjamin Tucker, Esq.
J. F. Vandercomb, Esq.

Foreign Member (1).

A. Risso, M.D.

The following Persons were elected Fellows during the year 1851.

January 22nd.—Thomas Webster Rammell, Esq., Gwydyr House, Whitehall; and Robert Rawlinson, Esq., Gwydyr House, Whitehall.

February 5th.—James Inglis, Esq., M.D., Green Royde, Halifax.
March 12th.—Charles Johnston, Esq., Southwick Crescent, Hyde Park; and Capt. Richard Strachey, of the Bengal Engineers.
—— 26th.—John Kirkpatrick, Esq., Inner Temple; and George Whitmore, Esq., Park Street, Grosvenor Square.
April 30th.—Edward John Hutchins, Esq., M.P., Lymington.
May 14th.—Samuel J. Mackie, Esq., Victoria Grove, Folkestone.
June 25th.—Lieut. H. U. Tyler, Royal Engineers.
November 5th.—Capt. Collinson, R.E., Gateshead.
—— 19th.—John Percy, M.D., Museum, Jermyn Street; and Starling Benson, Esq., Swansea.
December 3rd.—Thomas Arundell Tagg, Esq., Leyton, Essex; Rev. Henry Malcolm de la Condamine, Victoria Terrace, Blackheath; and Wentworth Blackett Beaumont, Esq., Bywell Hall, Newcastle-on-Tyne.
—— 17th.—Frederick Hindmarsh, Esq., Bucklersbury.

The following Persons were elected Foreign Members.

January 8th.—Herr Wilhelm Haidinger, Vienna; James D. Dana, Esq., New Haven, Connecticut; Herr Colonel G. Von Helmersen, St. Petersburg; and Prof. H. G. Bronn, Ph.D., Heidelberg.
June 25th.—Professor Angelo Sismonda, Turin.

The following Donations to the Museum have been received since the last Anniversary.

British Specimens.

Specimens of *Beyrichia complicata* in Llandeilo Flagstone; presented by Sir H. T. De la Beche, Director-General of the Geological Survey of Great Britain.
Specimens of Coal Plants from Ashton-under-Lyne; presented by Mr. Henry Woolven.
Specimens of Pinnæ, Panopæa, Pyrula, Venericardiæ, Voluta, Pectunculi, &c., from the Bognor Rock; presented by Ashurst Majendie, Esq., F.G.S.
Specimens of Corals, Nautilus, Ammonites, &c., from the Silurian, Lias, and Chalk; presented by W. R. Binfield, Esq.
32 Specimens of Fish-remains, from the Carboniferous Limestone of Armagh; presented by Capt. Jones, R.N., M.P., F.G.S.
24 Glazed Tablets, containing examples of Eulima, Rissoa, Marginella, and of other Genera from the Hampshire Eocene Deposits, with Lithographs of the same magnified; presented by the British Natural History Society.
Specimens of Ornithoidichnite from the Wealden, and 2 casts of the same, with a cast and bones of a Turkey's Foot; presented by S. H. Beckles, Esq.

74 Specimens of Fossils from the Barton beds; presented by Edward Charlesworth, Esq., F.G.S., and the British Natural History Society.

19 Specimens of Fossil Ophiuræ; presented by Sir P. G. Egerton, Bart., M.P., F.G.S.

Specimen of Paramoudra from the Chalk; presented by Rev. J. Gunn.

Foreign Specimens.

12 Specimens of Fossiliferous Rock, with Nerineæ, &c., from St. Thomas, West Indies; presented by Thomas Bland, Esq., F.G.S.

8 Specimens of Modern Rain-Prints from the Bay of Fundy; presented by Sir Charles Lyell, F.G.S.

3 Models of the Skull and Jaw of the Dicynodon; presented by the Royal College of Surgeons.

A series of Mineral and Rock Specimens from Peru; presented by Don Mariano E. de Riviero.

A series of Tertiary Fossils and Volcanic Rocks from South Australia; presented by Dr. Daniel Curdie.

A series of Cretaceous Fossils from Spain; presented by Don Ezquerra del Bayo.

Specimens of Limestone and Stalagmite, containing Bones of Birds, Snail Shells, &c., from a Cave at Bermuda; presented by J. D. Anderson, Esq.

13 Specimens of Shales with Fossil Fish, and of Bituminous Coal from Hilsboro', New Brunswick; presented by Dr. C. J. Jackson.

35 Specimens of Minerals and Rocks from Van Diemen's Land (part of the Tasmanian Contribution to the Exhibition of the Industry of all Nations); presented by the Royal Society of Van Diemen's Land.

A suite of Australian Fossils from Adelaide; presented by John Davis, Esq.

3 Specimens of Bituminous Coal and Shale from Hilsboro', New Brunswick; presented by Nathaniel Gould, Esq.

A series of Clays from a Well-sinking at George Town, Demerara; presented by Lieut.-Col. Hope, R.E.

A suite of Fossils from New Zealand; presented by W. J. Hamilton, Esq., Sec. G.S.

A suite of Minerals and Fossils from the Azores; presented by W. G. Terry, Esq., F.G.S.

CHARTS AND MAPS.

The Charts, &c., published by the Admiralty during the year 1850; presented by Rear-Admiral Sir Francis Beaufort, Hon. M.G.S., by direction of the Lords Commissioners of the Admiralty.

Maps, Nos. 17, 18, 55 (wanting N.E.), 56, 60, 61 (wanting S.E.), 74, 75, 76, 79, and Section No. 18 of the Geological Survey of Great Britain; presented by Sir H. T. De la Beche, F.G.S.,

Director-General of the Survey (on the part of Her Majesty's Government).

24 Charts and Plans, published by the Dépôt de la Marine, in 1850; presented by M. le Directeur-Général du Dépôt de la Marine.

Tabular View of the Order of Deposition of the Principal European Groups of Stratified Rocks, by Capt. R. Smith; presented by Mr. S. B. Oldham, the Publisher.

Topographical Map of London and its Environs, by R. W. Mylne; presented by the Author.

Trade Wind Chart of the Atlantic Ocean, by Lieut. M. F. Maury, U.S.N.; presented by the Author.

General Map of Florida, 1846; Map of Mineral Lands of Lake Superior; Hydrographical Basin of the Upper Mississippi River, by J. N. Nicollet; presented by the Smithsonian Institution, Washington.

Skeleton Chart of the World; presented by Mr. J. W. Lowry.

Swiss Geological Maps and Sections of the Cantons of Zurich and Glarus; presented by Sir R. I. Murchison, F.G.S.

Monthly Isothermal Lines of the Globe, by Prof. H. W. Dove, with Remarks; presented by William Hopkins, Esq., Pres. G.S.

Engraving of Sir R. I. Murchison, by Mr. Walker, in Frame; presented by Sir R. I. Murchison, F.G.S.

Lithographic Portrait of Leopold von Buch; presented by the Geological Society of Berlin.

Isometric Plan of the Chemical Laboratory, Queen's College, Cork; presented by C. B. Lane, Esq., F.G.S.

Coloured Lithograph of Minerals, in glazed Frame; presented by Prof. Tennant, F.G.S.

The following List contains the Names of the Persons and Public Bodies from whom Donations to the Library and Museum were received during the past year.

Abich, M. H.
Academy of Natural Sciences of Philadelphia.
Academy of Sciences of Bologna.
Academy of Sciences of Breslau.
Academy of Sciences of Dijon.
Academy of Sciences of Paris.
Admiralty, The Right Hon. the Lords Commissioners of the.
Albizzi, M. O. D.
American Association for the Advancement of Science.
American Philosophical Society.
Anderson, J. D., Esq.
Architect and Building Gazette, Editor of.
Athenæum, Editor of.

Beardmore, N., Esq., F.G.S.
Beckles, S. H., Esq.
Beke, Dr. C. T.
Berwickshire Naturalists' Club.
Binfield, W. R., Esq.
Binney, E. W., Esq.

Bland, T., Esq., F.G.S.
Bombay Branch Royal Asiatic Society.
Boston Society of Natural History.
Breton, Lieut. W.H., R.N., F.G.S.
British Association for the Advancement of Science.
British Natural History Society.
Brodie, Rev. P. B., F.G.S.
Bronn, Dr. H. G., For. M.G.S.
Buckman, Prof., F.G.S.

Calcutta Library.
Carpenter, W. B., M.D., F.G.S.
Carter, H. J., Esq.
Catullo, Prof. A. T.
Charlesworth, E., Esq., F.G.S.
Chemical Society of London.
Condamine, Rev. H. M. de la.
Curdie, Dr. D.

D'Archiac, M. Le Vicomte, For. M.G.S.
Darwin, C., Esq., F.G.S.
Daubeny, Prof., M.D., F.G.S.
Daubrée, M. A.
Davidson, Thomas, Esq.
Davis, John, Esq.
De la Beche, Sir H. T., F.G.S.
Delcros, M. le Commandant.
Delesse, M. Achille.
Dépôt Général de la Marine de France.
D'Orbigny, M. Alcide, For. M. G.S.

East India Company, The Hon.
École des Mines de Paris.
Egerton, Sir Philip G., Bart., M.P., F.G.S.
English, H., Esq.
Enniskillen, Earl of, F.G.S.
Erdmann, M. A.
Erman, M. A.
Ezquerra del Bayo, Don.

Faraday, M., Esq., D.C.L., F.G.S.
Fischer de Waldheim, Dr. G., For. M.G.S.
Fitton, Dr. W. H., F.G.S.
Fletcher, T. W., Esq., F.G.S.
Forchhammer, Prof., For. M.G.S.

Geological Society of Berlin.
Geological Society of Dublin.
Geological Society of France.
Glasgow Philosophical Society.
Gould, N., Esq.
Gunn, Rev. I.

Hamilton, W. J., Esq., Sec. G.S.
Hardy, Lieut., R.N.
Hausmann, Prof. J. F. L., For. M.G.S.
Hennessy, H., Esq.
Hopkins, Evan, Esq., F.G.S.
Hopkins, Wm., Esq., Pres. G.S.
Hope, Lieut.-Col., R.E.
Horticultural Society.

Imperial Academy of Sciences of St. Petersburg.
Imperial Academy of Sciences of Vienna.
Indian Archipelago Journal, Editor of.
Italian Society of Science of Modena.

Jackson, Dr. C. T.
Jäger, Dr. Georg.
Jerwood, James, Esq., F.G.S.
Johnston, A. K., Esq., F.G.S.
Jones, Capt. T., R.N., M.P., F.G.S.

Koch, Dr. Albert.
Koch, M. A. C.
Kokscharow, M. N.
Koninck, Dr. L. de.

Lane, C. B., Esq., F.G.S.
Lea, I., Esq.
Leeds Philosophical and Literary Society.
Leymerie, M. A.
Linnean Society.
Literary Gazette, Publishers of.
Literary and Philosophical Society of Manchester.
Liverpool Literary and Philosophical Society.

Lloyd, Col., F.G.S.
Logan, W. E., Esq., F.G.S.
Lowry, Mr. J. W.
Lyceum of Natural History, New York.
Lyell, Sir Charles, F.G.S.

Mackinnon, W. A., Esq., M.P.
Majendie, A., Esq., F.G.S.
Mantell, G. A., LL.D., F.G.S.
Martin, P. J., Esq., F.G.S.
Martins, C. M. D.
Maury, Lieut. M. F.
Meneghini, Prof.
Microscopical Society.
Murchison, Sir R. I., F.G.S.
Muséum d'Histoire Naturelle de Paris.
Museum of Practical Geology.
Mylne, R. W., Esq., F.G.S.

Natural History Society of Basle.
New College.

Oldham, S. B., Esq.

Palæontographical Society.
Perrey, Prof. A.
Pittard, S. R., Esq.
Prestwich, J., jun., Esq., F.G.S.
Prevost, Prof. Constant, For. M. G.S.

Ray Society.
Reeve, Lovell, Esq.
Riviero, M. E. de.
Rowlandson, T., Esq., F.G.S.
Royal Academy of Berlin.
Royal Academy of Sciences of Madrid.
Royal Academy of Munich.
Royal Academy of Stockholm.
Royal Academy of Turin.
Royal Agricultural Society of England.
Royal Asiatic Society.
Royal Astronomical Society.
Royal College of Surgeons.
Royal Geographical Society.
Royal Geological Society of Cornwall.
Royal Institution.
Royal Institution of Cornwall.
Royal Irish Academy.
Royal Society.
Royal Society of Edinburgh.
Royal Society of Van Diemen's Land.
Rush, G., Esq.
Ryckholt, M. le Baron P. de.

Sabine, Lieut.-Colonel, F.G.S.
Savi, Prof.
Scarborough Philosophical Soc.
Schäffer, Dr. T. K.
Schafhäutl, Dr.
Scharenberg, Dr. W.
Sedgwick, Rev. Prof., F.G.S.
Silliman, Prof., M.D., For. M.G.S.
Simpkinson, Rev. John.
Smithsonian Institution.
Société d'Agriculture, Science, Arts et Commerce, du Puy.
Société Impériale des Naturalistes de Moscou.
Société Linnéenne de Bordeaux.
Société de Physique et d'Histoire Naturelle de Genève.
Sorby, H. C., Esq., F.G.S.
Spence, W., Esq.
Spencer, J. F., Esq.
Spurr, J. de W., Esq.
Studer, Prof. B., For. M. G.S.

Tate, G., Esq., F.G.S.
Taylor, R., Esq., F.G.S.
Tennant, Prof., F.G.S.
Terry, W. G., Esq., F.G.S.
Turner, H. N., jun., Esq.

Vaudoise Société des Sciences Naturelles.
Von Buch, Baron Leopold, For. M. G.S.

Wetherell, N. T., Esq., F.G.S.
White, W., Esq.
Williamson, Prof. W. C.
Wisbaden Natural Hist. Society.
Woolven, H., Esq.
Wyld, James, Esq., M.P.

Yorkshire, Geological and Polytechnic Soc. of West Riding of.

List of PAPERS *read since the last Anniversary Meeting, February 21st*, 1851.

1851.

Feb. 26th.—On the Silurian Rocks of Scotland, by Sir R. I. Murchison, F.G.S. Part 2.

March 12th.—On the Fossil Plants of Scarborough, by C. J. F. Bunbury, Esq., For. Sec. G.S.

———— Additional Remarks on the Structure of the Calamite, by J. S. Dawes, Esq., F.G.S.

———— On Upright Calamites occurring near Pictou, by J. Dawson, Esq.; communicated by Sir Charles Lyell, F.G.S.

March 26th.—On the Boulder Clay of Caithness, by J. Cleghorn, Esq.; communicated by Sir Charles Lyell, F.G.S.

———— On the Erratic Tertiaries of Cheshire, and on the Scratched Boulders of the Till, by Joshua Trimmer, Esq., F.G.S.

———— On the Sequence of Events during the Glacial or Pleistocene Period, as evinced by the Superficial Accumulations of North Wales, by Prof. A. C. Ramsay, F.G.S.

April 9th.—On the Basement Beds of the Inferior Oolite in Gloucestershire, by the Rev. P. B. Brodie, F.G.S.

———— On the Physical Geography of North America, as connected with its geological structure, by Sir J. Richardson, M.D.; communicated by Sir Charles Lyell, F.G.S.

———— On the Erratics of Canada, by J. J. Bigsby, M.D., F.G.S.

April 30th.—Notice of the Occurrence of an Earthquake at Carthagena. (Forwarded from the Foreign Office, by order of Viscount Palmerston.)

———— On Fossil Rain Prints in the Recent, Triassic, and Carboniferous Periods, by Sir Charles Lyell, F.G.S.

———— On the occurrence of a Track and Footprints of an animal in the Potsdam Sandstone of Lower Canada, by W. E. Logan, Esq., F.G.S.

———— On the Footprints in the Potsdam Sandstone of Lower Canada, by Prof. Owen, F.G.S.

May 14th.—On the Angular Flint Drift of the South-East of England, and on its Distribution within and without the Wealden, by Sir R. I. Murchison, F.G.S.

———— On a Deposit containing Osseous Remains of Mammalia at Folkestone, by Samuel J. Mackie, Esq.; communicated by Sir R. I. Murchison, F.G.S.

May 28th.—On the Geological Structure of the Tagros Range of Western Persia, by W. K. Loftus, Esq., F.G.S.

———— On the Remains of Fish in the Silurian Rocks of Great Britain, by J. W. Salter, Esq., F.G.S.

———— On the Elevatory Forces that raised the Malvern Hills, by H. E. Strickland, Esq., F.G.S.

1851.

June 11th.—Section and Analysis of the Permian Strata at Astley, Lancashire, by G. W. Ormerod, Esq., F.G.S.

———— On a Fossil Fish from the Deccan, India, by Lieut.-Col. W. H. Sykes, F.G.S.

———— On the Physical Evidence of an Arctic Climate during the Formation of the Erratic Tertiaries of Great Britain, by Joshua Trimmer, Esq., F.G.S.

June 25th.—On the Geology of the Straits of Singapore, by J. R. Logan, Esq., F.G.S.

———— On the Boulder Clay at Linksfield Quarry, Elgin, by Capt. L. Brickenden, F.G.S.

———— On the Drift at Sangatte Cliff, near Calais, by Joseph Prestwich, Esq., F.G.S.

———— On the Gravel of the Guildford Valley, by R. A. C. Austen, Esq., F.G.S.

———— On the Geology of the Himalaya and Tibet, by Capt. R. Strachey, F.G.S.

Nov. 5th.—Notice of the Occurrence of an Earthquake at Chili. (Forwarded from the Foreign Office, by order of Viscount Palmerston.)

———— On the Devonian and Cambrian Rocks of Cornwall and Devon, by the Rev. Professor Sedgwick, F.G.S.

Nov. 19th.—On the Granitic Blocks of the South Highlands of Scotland, by William Hopkins, Esq., Pres. G.S.

Dec. 3rd.—On a curious Fossil Fern from the Coal at Cape Breton, by C. J. F. Bunbury, Esq., For. Sec. G.S.

———— On the Cambrian and Silurian Rocks which appear at the base of the Carboniferous chain of Yorkshire, near the Craven Fault, by the Rev. Professor Sedgwick, F.G.S.

Dec. 17th.—Note on the Quader-formation of Germany, by Prof. Geinitz; communicated by Sir Charles Lyell, F.G.S.

———— On the Causes of the Changes of Climate at different Geological Epochs, by William Hopkins, Esq., Pres. G.S.

———— Notice of the Discovery of Reptilian Foot-tracks and Remains in the Old Red Sandstone of Moray, by Capt. L. Brickenden, F.G.S.

———— Description of the *Telerpeton Elginense*, and Observations on supposed Fossil Ova of Batrachians in the Lower Devonian Strata of Forfarshire, by G. A. Mantell, Esq., LL.D., F.G.S.

1852.

Jan. 7th.—Notice of the Discovery of Boulders and Fossil Bones in clefts of the rock in Portland Island, by Mr. A. Neale; communicated by J. C. Moore, Esq., Sec. G.S.

———— On the Subescarpments of the Ridgeway Range, and their contemporaneous deposits in the Isle of Portland, by C. H. Weston, Esq., F.G.S.

Jan. 21st.—On the Quartz-rock of Scotland, by Daniel Sharpe, Esq., V.P.G.S.

1852.

Feb. 4th.—On the Southern Border of the Highlands, by Daniel Sharpe, Esq., V.P.G.S.

——————— On the Discovery of Gold Alluvia in Australia, by the Rev. W. B. Clarke, F.G.S.

——————— On the Anticipation of the Discovery of Gold in Australia, by Sir R. I. Murchison, F.G.S.

After the Reports had been read, it was resolved,—

That they be received and entered on the Minutes of the Meeting; and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved,—

1. That the thanks of the Society be given to Professor E. Forbes, and Daniel Sharpe, Esq., retiring from the office of Vice-President.

2. That the thanks of the Society be given to His Grace the Duke of Argyll, Sir H. T. De la Beche, Sir P. G. Egerton, Bart., M.P., the Earl of Enniskillen, and Capt. Henry James, retiring from the Council.

After the Balloting Glasses had been duly closed, and the lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

William Hopkins, Esq., M.A., F.R.S.

VICE-PRESIDENTS.

R. A. C. Austen, Esq., B.A., F.R.S.
G. B. Greenough, Esq., F.R.S. and L.S.
Sir Charles Lyell, F.R.S. and L.S.
Searles V. Wood, Esq.

SECRETARIES.

William John Hamilton, Esq.
John Carrick Moore, Esq., M.A.

FOREIGN SECRETARY.

C. J. F. Bunbury, Esq., F.L.S.

TREASURER.

John Lewis Prevost, Esq.

COUNCIL.

Prof. D. T. Ansted, M.A., F.R.S.
R. A. C. Austen, Esq., B.A., F.R.S.
John J. Bigsby, M.D.
James S. Bowerbank, Esq., F.R.S. and L.S.
C. J. F. Bunbury, Esq., F.L.S.
Prof. E. Forbes, F.R.S. and L.S.
Prof. T. Graham, F.R.S. L. and E.
G. B. Greenough, Esq., F.R.S. and L.S.
William John Hamilton, Esq.
J. D. Hooker, M.D., F.R.S. and L.S.
William Hopkins, Esq., M.A., F.R.S.
Leonard Horner, Esq., F.R.S. L. and E.
Sir Charles Lyell, F.R.S. and L.S.
G. A. Mantell, LL.D., F.R.S. and L.S.
John C. Moore, Esq., M.A.
Sir R. I. Murchison, G.C.St.S., F.R.S. and L.S.
Lieut.-Col. Portlock, R.E., F.R.S.
Samuel Peace Pratt, Esq., F.R.S. and L.S.
John Lewis Prevost, Esq.
Prof. A. C. Ramsay.
D. Sharpe, Esq., F.R.S. and L.S.
W. W. Smyth, Esq., M.A.
S. V. Wood, Esq.

Trust Accounts.

Receipts.	£	s.	d.	£	s.	d.
Balance at Banker's, 1st of January 1851, on the Wollaston Donation Fund	31	11	6			
Balance at Banker's, Geological Map Fund	2	15	0			
Total at Banker's, Jan 1st, 1851				34	6	6
Received on account of the Geological Map (sold)	11	10	0			
Dividends on the Donation Fund of 1084*l.* 1*s.* 1*d.* Red. 3 per Cents.	31	11	6			
				43	1	6
				£77	8	0

Payments.	£	s.	d.
Award to M. J. Barrande	28	11	6
Cost of Striking three Palladium Medals, one of which was awarded to the Rev. Prof. Sedgwick	2	4	0
Paid on account of Geological Map: Mr. Greenough, Balance of 1850	2	15	0
Balance at Banker's, Trust Account	43	17	6
	£77	8	0

We have compared the books and vouchers presented to us with these statements and find them correct.

DANIEL SHARPE,
JAMES TENNANT, } *Auditors.*

Jan. 28, 1852.

Valuation *of the Society's Property;* 31*st December*, 1851.

Property.	£	s.	d.	£	s.	d.
Due from Messrs. Longman and Co., on Journal, Vol. VII.				66	11	1
Due for Subscriptions to Journal				29	8	0
Balance in Banker's hands				538	17	4
Balance in Clerk's hands				1	4	10
Funded Property, 3792*l.* 3*s.* 11*d.* Consols				3600	0	0
Arrears of Admission Fees (considered good)	44	2	0			
Arrears of Ann. Contributions prior to 1851 (considered good)	15	15	0			
Arrears of Contributions of 1851	18	18	0			
				78	15	0
				£4314	16	3

Debts.	£	s.	d.
Due to Mr. R. Taylor, on Journal, Vol. VII.	37	16	0
Due to G. Laing, for House Repairs	15	8	6
Balance in favour of the Society	4261	11	9
	£4314	16	3

[*N.B. The value of the Mineral Collections, Library, Furniture, stock of unsold Transactions, Proceedings, Quarterly Journal, and Library Catalogue is not here included.*]

Jan. 28, 1852. J. L. PREVOST, *Treasurer.*

INCOME.

	£	s.	d.	£	s.	d.
Outstanding, 1850:						
Quarterly Journal, Vol. VI. (Messrs. Longman & Co.) paid June 14th				49	4	5
Balance at Banker's, January 1, 1851	430	3	1			
Balance in Clerk's hands	21	13	9			
				451	16	10
Compositions received	94	10	0			
Compositions received in December after Consols shut	63	0	0			
				157	10	0
Arrears of Admission Fees	6	6	0			
Arrears of Annual Contributions	22	1	0			
				28	7	0
Admission Fees of 1851				102	18	0
Annual Contributions of 1851				646	16	0
Dividends on 3 per cent. Consols				109	0	8
Sale of Transactions				112	9	9
Sale of Transactions in separate Memoirs				3	13	11
Sale of Proceedings				6	10	6
Journal, Vol. I., allowance on sale from the Publisher				0	15	0
Sale of Journal, Vol. II.				7	8	0
Sale of Journal, Vol. III.				8	13	6
Sale of Journal, Vol. IV.				13	6	6
Sale of Journal, Vol. V.				15	5	6
Sale of Journal, Vol. VI.				52	2	0
Sale of Journal, Vol. VII.				151	15	5
Sale of Library Catalogue				1	0	0

We have compared the Books and Vouchers presented to us with these Statements, and find them correct.

DANIEL SHARPE,
JAMES TENNANT, } *Auditors.*

Jan. 28, 1852.

£1918 13 0

Due from Messrs. Longman and Co., on Journal, Vol. VII. £66 11 1

Year ending December 31st, 1851.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Outstanding, 1850:						
Quarterly Journal, Vol. VI. (Mr. R. Taylor)				58	4	3
Compositions invested				94	10	0
General Expenditure:						
Taxes	28	15	5			
Fire Insurance	3	0	0			
House Repairs	7	6	8			
Furniture Repairs	17	18	4			
New Furniture	15	15	3			
Fuel	30	19	0			
Light	31	18	6			
Miscellaneous House Expenses, including Postages	46	8	8			
Stationery	24	4	4			
Miscellaneous Printing	17	19	0			
Tea for Meetings	21	3	2			
				245	8	4
Salaries and Wages:						
Assistant Secretary and Curator	200	0	0			
Clerk	115	0	0			
Porter	80	0	0			
House Maid	33	4	0			
Occasional Attendants	10	0	0			
Collector	20	12	3			
				458	16	3
Library				57	6	2
Museum				3	9	1
Diagrams at Meetings				16	8	6
Miscellaneous Scientific Expenses				7	12	6
Admission Fee, repaid in part				4	4	0
Contributions of 1851 repaid				6	6	0
Publications:						
Transactions	1	0	0			
Transactions, separate Memoirs	2	3	8			
Journal, Vol. I., Copies for presentation, &c.	3	18	0			
Journal, Vol. II.	0	5	0			
Journal, Vol. III.	1	19	3			
Journal, Vol. IV.	2	6	2			
Journal, Vol. V.	0	16	0			
Journal, Vol. VI.	3	18	3			
Journal, Vol. VII.	401	11	5			
Journal, Vol. VIII.	6	0	0			
Proceedings	2	8	0			
				426	5	9
				1378	10	10
Balance at Banker's, Compositions received in December after Consols shut, to be invested				63	0	0
				1441	10	10
Balance at Banker's, Dec. 31, 1851	475	17	4			
Balance in Clerk's hands	1	4	10			
				477	2	2
				£1918	13	0
Due to Mr. R. Taylor, on Journal, Vol. VII.	37	16	0			
Due to G. Laing, for House Repairs	15	8	6			
	£53	4	6			

ESTIMATES *for the Year* 1852.

INCOME EXPECTED.

	£	s.	d.
Account due by Messrs. Longman and Co. in June, on Journal, Vol. VII.	66	11	1
Due for Subscriptions on Quarterly Journal	29	8	0
Arrears (See Valuation-sheet)	78	15	0
Ordinary Income for 1852 estimated:			
Annual Contributions (200 Fellows)	630	0	0
Admission Fees:			
Residents (6)	37	16	0
Non-residents (6)	63	0	0
	100	16	0
Dividends on 3 per Cent. Consols	112	0	0
Sale of Transactions, Proceedings and Catalogue	10	0	0
Sale of Quarterly Journal	240	0	0
Balance, probable Excess of Expenditure over Income, in diminution of Cash Balance	17	7	11
	£1284	18	0

J. L. PREVOST, TREASURER.

Jan. 28, 1852.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
Bill due to Mr. R. Taylor, on Journal, Vol. VII.				37	16	0
Bill due to G. Laing, for House Repairs				15	8	6
General Expenditure:						
Taxes	22	9	6			
Fire Insurance	3	0	0			
House Repairs	10	0	0			
Furniture Repairs	15	0	0			
New Furniture	20	0	0			
Fuel	31	0	0			
Light	32	0	0			
Miscellaneous House Expenses	46	0	0			
Stationery	30	0	0			
Miscellaneous Printing	20	0	0			
Tea for Meetings	22	0	0			
				251	9	6
Salaries and Wages:						
Assistant Secretary	200	0	0			
Clerk	120	0	0			
Porter	80	0	0			
House Maid	33	4	0			
Occasional Attendants	10	0	0			
Collector	22	0	0			
				465	4	0
Library, Binding and Additions				50	0	0
Museum				5	0	0
Diagrams at Meetings				15	0	0
Miscellaneous Scientific Expenses				5	0	0
Publications, Quarterly Journal				420	0	0
„ Transactions, &c.				20	0	0
				£1284	18	0

PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

20TH FEBRUARY, 1852.

AWARD OF THE WOLLASTON MEDAL AND DONATION FUND.

AFTER the Reports of the Council had been read, the President, W. Hopkins, Esq., delivered the Wollaston Palladium Medal to Dr. W. H. Fitton, F.R.S., F.G.S., addressing him as follows:—

DR. FITTON,—It is with great pleasure that I now proceed to perform the duty which devolves upon me of presenting to you the Wollaston Medal, which the Council of the Society has awarded to you. It would be in vain on an occasion like the present to attempt the enumeration of all the publications by which you have aided the advance of our science. During the period of more than forty years, you have contributed to that end, not only by your original papers, but also by sketches of the history of the science, and by reviews of the geological labours of others, always written in a style which rendered them attractive, and with a perspicuity which rendered them instructive, to the general reader. The Council, however, could not fail to recognize especially, in the award of this Medal, the merit of those papers in which you so clearly explained the nature of the different beds between the Chalk and the Oolites, and their relations to each other—relations which had been previously so imperfectly understood. The Upper Green Sand was sometimes confounded with the Lower Green Sand, the Gault with the Weald Clay, and the Ferruginous Sands of the Lower Green Sand with those of the Hastings Sands; and the distinctions between the Lower Green Sand, the Wealden Clay, and the Hastings Sands were imperfectly comprehended. In your communication to the 'Annals of Philosophy' in 1824, entitled "Enquiries respecting the Geological Relations of the Beds between the Chalk and the Purbeck Limestone in the South of England," you rectified much of this confusion; and in your excellent and elaborate memoir, entitled "Observations on some of the Strata between the Chalk and the Oxford Oolite in the South of England," you completely established those general characters of the beds in question, and the relations between them, which are now universally recognized. I cannot forego the pleasure of bearing personal testimony to the accuracy of the details of this memoir, having availed myself of it as a constant guide in my own researches throughout the same district. I must here also make especial mention of your 'Stratigraphical Account of the section from Atherfield to Rocken End,' on the south-west coast of the Isle of Wight, read before this

Society in 1845. Nature presents to us, along the southern coast of that island, one of the most perfect sections we possess for the study of those two great operations of deposition and upheaval by which so many parts of the earth's surface have been affected. You have availed yourself of the facilities which this natural section affords to describe it in accurate detail between the points above-mentioned; and you have also given us the most complete list we possess of the Lower Green Sand fossils of that locality, with a tabular arrangement of them which presents at once the clearest view of their stratigraphical distribution. By means of this beautiful section, combined with some of your previous observations, you have been enabled clearly to point out to us the true relations and the close resemblance between the lower beds of the Lower Green Sand and the *Terrain néocomien* of continental geologists, and to correct the error into which some of them had fallen in supposing the latter beds the equivalent of the Wealden beds of our own country.

In conclusion let me congratulate you on this recognition of your geological labours by those with whom you have been so long associated. I can scarcely help regarding this award as the realization of a hope which we may so easily conceive to have sometimes arisen in the mind of the illustrious founder of the Medal, that it might become, as it is become this day, the means of conferring well-merited honour on one of his old associates, to whose zeal and earnestness in the prosecution of geological research he must himself have been able to bear such ample testimony.

Dr. Fitton replied,—

Sir,—It is surely unnecessary to say, that I have the highest gratification in receiving this honour at your hands. To obtain any testimony of approbation from a body of men, amongst whom some of the happiest years of my life have been passed, would, under any circumstances, have been most grateful: but when I look at the list of persons who have already received this Medal, I regard it as a great honour that my name should be added to the number; and only regret that the result of my labours has not been more valuable and important; knowing well that my performance fell far short of what I myself hoped and intended.

Some of the principal subjects of my Papers have been very often considered in this room; and you have so well stated—if not with too much kindness—the grounds upon which the Council have thought me deserving of reward, that I could have little to add, even if the present were a proper occasion for geological discussion. But allow me to say, that, from personal considerations, this Medal has for me peculiar value. Dr. Wollaston had been, for many years before his death, one of the kindest friends whom I have ever known. I could mention, indeed, but one other person (and he, fortunately, still remains), whose unvaried friendship, during a large and critical portion of my life, was of such essential service to me; whilst their conversation was an unfailing source of instruction and delight. Of such friendships one may be justly proud. At the close of 1828, as Pre-

sident of this Society, I had the honour of communicating to the Council the Donation, under which the Medal now bearing Dr. Wollaston's name was instituted:—and, not many days afterwards, it became my duty to notify his death from the Chair. The Medal is stamped with his portrait; and you can judge how highly it will be prized, both by my family and myself.

The President then addressed MR. MORRIS as follows:—

MR. MORRIS,—I have now the pleasure of presenting to you the balance of the proceeds of the Wollaston Fund, which the Council have awarded to you this year in consideration of the forthcoming new edition of your 'Catalogue of British Fossils.' The accumulation of new species has of late years been so rapid that such a work can only be rendered adequate to meet the constantly increasing demands of geologists by new editions, requiring renewed research and continued labour on the part of the author. You have not shrunk from the task of bringing your work up to the standard required, though, we fear, with little prospect of pecuniary recompense adequate to your labours. The Council, therefore, have much satisfaction in offering you such aid as the Wollaston Fund places at their disposal, and hope that you will regard this award as an indication of their high estimation of your work.

MR. MORRIS briefly replied.

After the other proceedings had been completed, and the Officers and Council had been elected, the President proceeded to address the Meeting.

ANNIVERSARY ADDRESS OF THE PRESIDENT,

WILLIAM HOPKINS, Esq.

GENTLEMEN,—Before I proceed to discuss the scientific subjects on which I may have on this occasion to address you, it becomes my duty, according to the established custom of our Society, to lay before you some brief notices of those most distinguished for scientific attainments, among the late Fellows of the Society, whose deaths we have had to regret in the course of the past year.

DR. KIDD, late Regius Professor of Medicine in the University of Oxford, was formerly a King Scholar of Westminster, and about 1798 was elected a Student of Christ Church. In 1803 he was elected, by Convocation, Aldrichian Professor of Chemistry, being the first holder of that Professorship immediately after its being founded under the will of Dr. Aldrich. In this branch he was a popular and instructive lecturer. He also gave, voluntarily, courses of lectures on the sciences of Mineralogy and Geology, the latter of which, especially, was then

first rising into notice. We cannot but dwell with deep interest on these early recognitions of the value and interest of our science. Nor is the debt which Geology owes to Dr. Kidd to be estimated merely by these voluntary efforts in her favour; for he made the importance of such lectures so apparent, that they were afterwards established by grants from the Crown, and in the hands of Dr. Buckland, who was appointed to them in 1813, became so justly celebrated. At this period Dr. Kidd contributed to the progress of the different subjects on which he lectured, by various original papers and elementary treatises. He exhibited also the influence of that kindly social feeling which, in a teacher of youth, may sometimes become, in its indirect influence, scarcely of less importance than the instruction which he may directly communicate. He made a point of inviting to his table, and introducing to each other, those who were likely to become fellow-labourers in the fields of science. The friend to whom I am chiefly indebted for these particulars was a frequent guest of Dr. Kidd's at these social parties, and speaks of them with affectionate remembrance; and we cannot ourselves hear of them without a feeling of interest, when we learn that it was on such occasions that the names of Buckland and Conybeare first became associated both in private and geological intercourse. Dr. Kidd also, in the same social and liberal spirit, was chiefly instrumental in encouraging visits of the leading savants from London and elsewhere, every Whitsuntide, to Oxford, and of thus promoting their intercourse with the resident members of that University.

In 1822 Dr. Kidd became Regius Professor of Medicine. In this capacity he gave remarkably interesting lectures, especially in the department of comparative anatomy. He was particularly happy also in applying the results of his classical studies to the purposes of modern science, and was the first to call attention to the merits of Aristotle's zoological arrangements, and to point out their close agreement with the classification of Cuvier.

The Rev. WILLIAM KIRBY was born in the year 1759, at Witnesham Hall, in the county of Suffolk, the residence of his father, who was by profession a solicitor. He received his education at the Grammar School at Ipswich, and afterwards entered the University of Cambridge, at Caius College, where he took his degree of B.A. in 1781. The year following the Rev. Nicholas Bacon nominated him to the joint curacies of Barham and Coddenham, and afterwards proved the high estimation in which he held him by bequeathing to him the next presentation to the rectory of Barham, to which he was inducted in 1796. He resided there till his death.

Mr. Kirby affords a striking instance of the manner in which the strongest aptitude of our minds may remain dormant and unknown even to ourselves, till awakened by some accidental and perhaps trifling circumstance. His first attention was drawn to Entomology, as he has himself related, by his observing on his window a yellow cowlady, his admiration of which led him to collect other insects, and finally to prosecute the study of that branch of natural history till he

became, as you well know, one of the leading entomologists of the day. This is not the place to enumerate his entomological memoirs. He wrote a great number, many of which are to be found in the Linnæan Transactions and the Zoological Journal. I need scarcely remind you that the 'Introduction to Entomology,' written in conjunction with his friend Mr. Spence, and his Bridgewater Treatise, 'On the History, Habits and Instincts of Animals,' rendered him one of the most popular writers of the time on such subjects. He was not professedly a geologist, but always took a great interest in the science, and, in the course of his scientific rambles, made a point of collecting geological specimens of interest. He thus formed a large geological collection, and took great pleasure in exhibiting it to his friends.

Few men have ever gained the respect and affection of a large circle both of private and scientific friends, to so great an extent as Mr. Kirby. His life was spent in the simple and earnest search of knowledge among God's works, and the equally simple and earnest teaching of His word to those among whom he dwelt as their pastor for the long period of sixty-eight years.

Mr. Richard Cowling Taylor, the third son of Mr. Samuel Taylor, was born at Banham, in the county of Norfolk, January 18, 1789. He was cousin to Mr. Richard, Mr. John, and Mr. Philip Taylor, men so well known and so highly respected among us. He appears to have prepared himself early in life for the profession of a mining engineer, in which he afterwards rose to great eminence in America. He had the advantage for some time of being associated in business with Mr. William Smith, to whom the early geology of this country was so much indebted, and directed his attention assiduously to economic geology as a branch of his profession. The first work, however, by which he became known to the public, was one on the monastic remains of Norfolk, the 'Index Monasticus in the ancient kingdom of East Anglia,' which was followed by another work on antiquities, the 'General Index to Dugdale's Monasticon Anglicanum.' He was afterwards engaged in the Ordnance Survey of this country, but, about the year 1830, he was induced to go over to America, where he remained until his death, in the practice of his profession, in which his extensive knowledge, good judgement, and honourable character procured for him well-merited distinction.

In 1823 Mr. Taylor published a paper "On the Crag Strata of Cramerton, near Norwich;" and in the same year another "On the Alluvial Strata, and on the Chalk of Norfolk and Suffolk, and on the fossils by which they are accompanied." He also published in the Transactions of our Society (1830), previously to his leaving England, a paper entitled "Notice of two Models and Sections of about eleven square miles, forming a part of the Mineral Basin of South Wales in the vicinity of Pontypool." In America he published, in the Transactions of various Scientific Societies, a number of Geological Memoirs, chiefly on subjects associated more or less with his professional avocations; but his most important work was the 'Statistics of Coal,'

published at Philadelphia in 1848. It contains a general geographical and geological account of all kinds of coal, illustrated by maps and sections, together with statements drawn from official reports, of the production, consumption, and commercial distribution of coal in all those countries in which it is chiefly produced. To this work Mr. Taylor devoted latterly a large portion of his time. It contains an immense amount of valuable and carefully arranged statistical knowledge on the subject, not to be found in any other work.

Mr. Richard Phillips, Chemist and Curator of the Museum of Practical Geology, died on the 11th of May, in the seventy-third year of his age. Throughout a long series of years he prosecuted the study of Chemistry with great success, and made numerous contributions on that subject to various scientific societies and periodicals. In early life he was the intimate friend of Davy and Wollaston, and though never professing to devote much time to the study of Geology, he was one of the original founders of our Society. During the last two years he was President of the Chemical Society.

I have also to record the death of Mr. Vandercomb. In conducting the affairs of the Society during a critical period, the Council found him on several occasions a willing and judicious adviser. His legal ability and experience were placed gratuitously at their disposal; and I may mention, not only for the information of our own body, but for that of several kindred societies younger than our own, that it was through his instrumentality that we were enabled to obtain from the Crown a charter of incorporation less complex in its details and more liberal in its provisions than had previously been granted to any other scientific institution.

Gentlemen,—In the wide range which geology now presents to us, it has not been without some perplexity that I have determined on the form of the Annual Address which I am now called upon to make to you. The more frequent precedent afforded by similar addresses would suggest a general analysis or review of what has been done, especially in our own Society, during the past year; and this appears to me one obvious and useful object of such addresses. At the same time I think it right that each of your Presidents in succession should judge for himself as to the manner in which he may best fulfil his mission, and adopt that course which he may feel himself capable of rendering most subservient to the progress of our science. You will recollect that during the past year we have been much occupied in discussing the superficial accumulations now generally designated as "Drift." Our Quarterly Journal of the past year contains a considerable number of papers, and some elaborate ones, bearing more or less immediately upon it. It is a branch of our science, too, which has been making of late great progress, but in which much yet remains to be done before we arrive at a complete knowledge of the phænomena, and those sound theoretical views which may command something like unity of assent. For these

reasons I have determined to make this subject the leading one of my address. In doing so I shall not restrict myself to a mere analysis of the communications which have been made to us. I shall venture to criticize them with such freedom as may, I trust, require no further apology than that which the desire of advancing our science may afford. I shall also, before I enter on this more detailed analysis, endeavour to bring before you a general view of some of the more important parts of the subject, under the aspect which it now presents to us. Papers also on other subjects have been brought before us, which are far too important to be omitted in any general review of our proceedings, and to which I shall in the sequel direct your attention.

If the period of the Drift involved only a repetition of the action of those geological causes which we recognize in earlier geological periods, it would still have an especial interest, as approximating to our own times, and as less likely than those earlier periods to have the nature and character of its operations and phænomena masked by those of succeeding periods. But besides this, we have reason to regard it as a period of peculiar conditions, and of phænomena referable to peculiar causes, the study of which has opened to us entirely new views respecting the agencies which have so marvellously modified the face of our planet, by the continual transference of matter from one part of its surface to another. The study of this period has also led us to a knowledge of climatal conditions not before suspected, and to various researches into the causes which may have produced those conditions; and thus we have extended our knowledge of one of the most interesting branches of terrestrial physics.

There is perhaps no branch in which speculative geology has recently made more satisfactory progress, than in theoretical views respecting the agencies by which the larger masses associated with the Drift, the erratic blocks, have been transported from one locality to another. At the same time no subject, perhaps, has been more characterized, in passing through its various phases, by extreme hypotheses and premature conclusions. When water alone was recognized as the means of transport, hypotheses were sometimes made respecting the magnitudes of single waves, and their passage even over elevated mountains, which nearly all of us should now agree in condemning as extravagant; and effects were attributed to them which, from the transitory character of any single wave, were not only improbable, but perhaps physically impossible. In the abandonment of such extreme hypotheses we have made a most salutary step. Nor was the introduction of the glacial theories of transport by glaciers and floating ice, unattended by hypotheses, which might be deemed extreme hypotheses with as much propriety as those which were condemned as extravagant in the agency of water. It is manifest, however, that these extreme views are gradually but surely giving way in favour of those more moderate, and as I believe sounder views to which we appear to be rapidly converging.

The glacial theories of transport of erratic blocks made rapid progress among us soon after their first announcement, although received

by many geologists in the first instance with great reservation. One reason of this reserve was, I imagine, the difficulty of conceiving a change of temperature such as required by those theories, exactly opposite to the changes which the geologist had ever contemplated, a change after the glacial epoch from a lower to a higher temperature. Increased knowledge, however, of the causes affecting climatal conditions have enabled us to remove in great measure this source of doubt. Another reason for hesitation in accepting these theories was, perhaps, to be found in the incautious manner in which their claims were asserted by some of their first advocates, and the unlimited application which were made of them to account for the phænomena of transported materials of all kinds. Whatever truth might belong to the facts adduced in support of these theories, it was clear that much of the reasoning founded upon them was untenable. Overstrained applications, however, of physical theories are almost the necessary consequences of their early reception by minds animated by an ardent zeal for the discovery of new scientific truths; and perhaps this tendency, in certain stages in the progress of science, may be almost necessary to counteract the hesitation of those whom natural timidity, or possibly severer mental discipline and more accurate physical knowledge, may have rendered too slow in the recognition of the germs of new theories, while supported, perhaps, by little of demonstrative evidence. All doubts, however, as to these theories being founded in truth, whether there might be more or less of exaggeration in the advocacy of them, soon gave way before the evidence collected by northern voyagers respecting the action of icebergs, and that supplied by Agassiz, Charpentier, Forbes, and others, who devoted themselves to the study of the constitution and motion of glaciers. Almost all geologists, I conceive, now agree in the opinion that both floating and terrestrial ice have played their part to a greater or less extent in the transport of erratic blocks.

The theories of Agassiz and Charpentier as to the causes of glacier motion have been refuted by the exact admeasurements made not only by Prof. Forbes, but by those of Agassiz himself; and the speculative views of the latter philosopher on the former extension of glaciers over the surface of a large portion of the northern hemisphere are no longer received. But, Gentlemen, geologists would be ungrateful, if, while they acknowledge, as we all do, the great value of the researches of our countryman Prof. Forbes on the Alpine glaciers, they should in any degree forget the debt they owe to the distinguished Swiss naturalist and his countryman, who were the first to point out the effects of glaciers in smoothing and striating rocks, to urge their effectiveness in the transport of blocks, and to indicate phænomena of a past epoch similar to those of the present time, in such a manner as to command the attention of geologists, and finally to lead to the adoption of our present views respecting the glacial epoch. It is especially to M. Agassiz and his ardour in the pursuit of scientific truth that we owe the first knowledge of this subject in our own country. His visits here, and the personal favour with which he was received among us, gave him frequent opportunities of

expounding his views; and I cannot refrain on this occasion from expressing the delight with which I call to mind the open-hearted hospitalities which he exercised in the deep recesses of the Bernese Alps, and from testifying to the perfect unreserve with which he communicated his views to those alike who favoured or opposed them.

I have already remarked that water was formerly almost the only recognized agent in the transport of erratic blocks. On the introduction of the glacial theory it was superseded, and appeared to be almost forgotten, nor does it still seem to have regained what I conceive to be its just claims, in the minds of many geologists. On the abandonment, however, of some of the unreasonable claims of the glacial theories, and the distinct recognition of large portions of drift as subaqueous phænomena, the importance of currents as agents of transport gained more attention, though there are probably many persons who yet fail to realize in their own minds the enormous power which such currents may possess, even without greater velocities than may be easily allowed them. This power arises from the fact, which I have elsewhere demonstrated, that the moving force of a current, estimated by the weight of a block of any assigned form and material, increases as the *sixth power* of the velocity of the current. It is this which accounts for the circumstance that the same atmosphere which in one state of motion constitutes a summer breeze, but just sufficient to move the leaf or the flower, exerts at other times the almost irresistible force of the storm. It is on this account, too, that, reasoning from the power of ordinary currents of two or three miles an hour, we are liable to miscalculate so entirely the force of a rapid current.

I consider the distinct recognition of these three agencies of transport—glaciers, floating ice, and currents—as essential to the final establishment of sound theoretical views on this subject, and the great majority of geologists are probably prepared to recognize them to a greater or less extent. It is equally essential that we should be prepared to assign to each of these agencies its share in the great work of transport according to the characters of the transported materials; for it is alone by a careful study of these distinctive characters that we can hope to decide by what agent the transport has been effected. On this point there appears to be still much discrepancy of opinion, when the test has to be applied to individual cases. These differences of opinion seem to manifest themselves principally on questions relating to the action of water, either with reference to the form in which currents tend to deposit a general mass of drift, or to their effect in rounding and wearing the individual component parts of it, as compared with the tendency of other modes of transport to produce similar effects. It may be that we have not yet studied these effects as referable to different causes with sufficient care, or that we are still too much influenced individually by preconceived notions; but it is certain that different persons do draw very different inferences as to the mode of transport of a given mass of drift, from the characters which its component materials present. In some cases

such inferences will probably ever remain doubtful, but in others there can be no reasonable grounds for doubt. Most geologists appear now to agree about what may be regarded as the two extreme cases, and admit small rounded pebbles as a proof of long-continued aqueous action, and very large erratics with perfectly unwoven angles as equally indicative of transport by ice. If there be any among us not glacialists to this extent, I recommend them to the personal study of these blocks. I well recollect, in my own case, that after resisting all verbal arguments in favour of glacial theories, I stood at once convinced under the silent appeal of the *Pierre à bot* on my visit to that magnificent erratic of the Jura. In almost all the cases intermediate to these extremes, I fear we have much yet to reconcile before we come to any unity of opinion. And here, Gentlemen, let us ask ourselves in the spirit of candour, whether one cause of this may not be found in our natural tendency to hold too pertinaciously to preconceived opinions. It will not be denied by any one, I imagine, that it would generally be the *necessary* consequence of a transitory current driving a mass of drift over a level surface, to spread it out in an approximately equable layer; while such a result could generally be regarded as only the *accidental* consequence of transport by floating ice. Such a layer would indicate the latter as a *possible* mode of deposition, the former as a highly *probable* one. When the glacialist contends for the *possible* rather than the *probable* mode, let him examine himself strictly whether he may not be unconsciously under the dominion of preconceived theoretical views. Again, the polishing of rocks and their striation in definite directions may be generally regarded as the *necessary* consequences of the passage over them of a large mass of ice, preserving its general direction of motion in defiance of merely local obstacles. Such effects *might* also be produced by the passage of masses of detritus. The former is a *probable*, the latter a *possible* mode of producing these phænomena. When the opponent of the glacialist, therefore, urges the latter against the former mode of action (except under some particular conditions), let him also institute a self-examination as to whether he is exercising his unclouded and unprejudiced judgment. Gentlemen, I would exhort you earnestly to prosecute your researches and speculations with a fair and liberal feeling towards the views of others, and especially with an unflinching obedience to the laws of inductive philosophy. Every geologist, who takes an impartial review of the history of his own mind with reference to geological opinions, will probably feel that what is termed consistency of opinion would frequently have been in his own case persistency in error. I feel the more entitled to make these remarks, from the consciousness of having resigned much of my own early convictions respecting the glacial theory; and I make them in immediate connexion with the subject before us, because I believe that much remains to be done in these superficial deposits before we can completely interpret them; and I believe also that for our progress towards sound opinion and unity of view respecting them, ability and fidelity in the observer will scarcely be more necessary than that fairness and candour without which he will

assuredly fail to bring his observations as true tests of the different views with which the subject is at present perplexed. Let us not seek for mere *possibilities* in support of antecedent opinions, but submit our views constantly to the test of enlarged experience and careful induction. There may be, doubtless, a stage in the progress of science in which new views, thrown out at random, and the advocacy of individual opinion with somewhat more than philosophical pertinacity, may be effective in the development of truth; but there is assuredly also another and more advanced stage of science, in which such habits of mind can only retard and embarrass its progress, and impede our arrival at those ultimate truths which it may be our object to establish. At this latter stage I believe the science of geology to have arrived; and if by these remarks I should induce one speculative geologist to watch with increased rigour the reasoning by which he arrives at his convictions, I shall perhaps have done more for our science than I can do by any detailed information which an occasion of this nature may enable me to bring before you.

I shall now direct your attention to some of the leading characters of the great mass of drift which extends over so large a portion of northern Europe. And first I shall speak of the *striæ* which so abound in the northern part of the region in question. When regarded with reference to a limited area, their directions might be described as characterized by the law of parallelism; but when regarded with reference to the whole region, we find them really characterized by the law of divergency. To those observers who had not examined the striæ on the shores of the North Sea, some point lying to the north of those shores, and nearly in the direction of Spitzbergen, seemed best to represent the centre of this divergence; but subsequently M. Böhtlingk observed striæ descending from Kemi eastward to Onega Bay, on the shores of which it is situated, and on the northern coast of Lapland, he also observed them descending from the high lands northward to the sea. These observations have also been corroborated by other observers. Around the district comprising the mountains of Scandinavia striæ appear to exist, directed to almost every point of the compass, and the characters of their divergency generally for the whole region may be considered as established.

The directions in which the detrital matter has moved in its transport across a particular locality cannot, of course, be ascertained with entirely the same accuracy as those of the striæ; but the erratic blocks can in numberless instances be identified with the rocks of a particular locality, and thus the *mean* direction in which a particular block has travelled can be determined with great accuracy. All the blocks, however, originating in the same locality have not been transported in the same direction. M. Durocher has noticed especially a granular granite, easy to be recognized, of which the original site is in the department of Vibourg in Finland. The extreme directions in which the blocks have proceeded from this spot comprise an angle nearly equal to two right angles. The *mean* direction, however, of these blocks, and that along which, or nearly so, the greatest number have

proceeded, is very approximately coincident with the directions of the striæ along the same line. A similar law holds with respect to other blocks which can be traced to their respective original sites. It may therefore be asserted as a law in this region, that the general or mean directions of transport are approximately coincident with the directions of the striæ.

If we refer to the analogous phænomena of Scotland, we find the general law which characterizes them is exactly that above enunciated; but when we examine the details of this latter case, it appears that the general law is only approximately true, for the law of divergency does not accurately hold with reference to one general centre, but with reference to a number of particular centres. This I have proved in the memoir on the granitic blocks of the South Highlands of Scotland, inserted in the last Number of our Journal, with respect to the granitic nucleus of Ben Cruachan, and that of the group of mountains immediately on the west of the northern part of Ben Lomond. To complete our knowledge of the Scandinavian striæ, it is necessary to ascertain whether such particular centres are found also in the mountainous district of that region. This is one of the points to which I would especially direct the attention of observers.

So long as we restrict ourselves to the Highlands of Scotland, we easily recognize the circumstances which have determined the particular directions which the blocks have taken. They have followed the valleys which must have existed previously to their dispersion, wherever those valleys were sufficiently defined to govern the operation of the transporting agents. And this would appear also to have been the case in the more immediate vicinity of the Scandinavian chain. We may consider the striæ, then, to represent the general direction of transport, and we find them, as laid down on the map of M. Sefström, exactly coinciding with the directions of the river-valleys descending from the mountains. So perfect a coincidence leaves little doubt of the influence of the pre-existing valleys in the direction of transport. But as we recede from the mountainous district, even in the limited space between the Highlands and the eastern coast of Scotland, the configuration of the country no longer presents, in many parts, those determinate features which would necessarily give a definite direction to the masses transported across it; and how much more is this true with respect to the widespread plains of northern Russia and of northern Germany! And yet, in all these cases, the directions of the striæ obey with wonderful regularity the same law of divergency as those nearer to the central chain. We may easily understand how glaciers would descend down the mountain-valleys, and, after reaching the level of the sea, how the ice would float along the submarine continuations of the same valleys, leaving striæ along them, without the power of deviating from a fixed direction; but after having escaped from the valleys on the immediate flanks of the central mountains, what cause can have operated to drive forward through the more open sea these masses of ice, or the masses of other materials which may have been the striating and grooving agents, in the same continuous direction,

and with such a force and determination that they could not be turned aside by the numerous projecting bosses of solid rock on which they have so effectively engraved the record of their transit? According to the hypothesis which we shall probably all be ready to adopt, the more elevated parts of the Scandinavian range must, at the period we are referring to, have formed an island, round which ordinary ocean-currents may possibly have passed in any direction; but the notion of such ordinary currents diverging in such various directions radiating from the central portion of this Scandinavian island, can only be spoken of as an absurdity. And yet no other force has ever been suggested, or is perhaps conceivable, except that of currents, as efficient to drive large icebergs or a mass of looser materials in a determinate direction, in defiance of numerous opposing obstacles. It appears to me, therefore, that we are driven to the alternative either of rejecting all theory on the subject, or of adopting that which would attribute these currents to *waves of elevation*, resulting from frequent, sudden, but not extensive vertical movements of the central range of elevated land; movements which we may conceive to have been thus repeated while the mean movement of the whole region was one either of gradual depression or of elevation.

And here I would make an observation which may not perhaps be without its theoretical value. Adopting this view of the subject, we may conceive the centres of the elevatory movements to have been different at different times, and consequently the directions of the corresponding currents produced by them to have been different, as in fact they would appear to have been from the different directions in which the transported matter has been driven from the same original site. But the movements which would send forth the greatest quantity of floating ice would be those which more immediately affected the line of coast; and the coast being deeply indented, as it must have been, by the present river-valleys when submerged, torrents would be simultaneously discharged from their mouths which would determine in a material degree the resulting current in the open sea; and since these valley-currents would necessarily have always the same directions, they would tend to impress approximately the same constant direction on the resulting ocean-current, whatever might be the precise centre of the elevatory movement. This influence however would, of course, be principally felt at points least remote from the then existing coasts.

When we pass to the great field of northern drift which the continent of North America presents to us, it is not perhaps without some feeling of disappointment that we find the directions of the striæ and those of transport without any distinct character of divergency either from local centres or from a general one. The observations described in Dr. Bigsby's paper on the "Erratics of Canada," were made before the importance of striated and polished rocks had been recognized, or we should doubtless have obtained much valuable information respecting them from so careful an observer. We learn however from the American geologists that the striæ preserve an approximate parallelism in a north-westerly and south-easterly direc-

tion over the north-eastern part of the North American continent, and that the erratic blocks and other transported matter have come in the same direction. In northern Europe, when the striating agents had quitted the Scandinavian mountains, they met with no other mountains of sufficient magnitude to impede their general course, or materially modify the directions of movement; but in America the striation, according to the American geologists, has been carried not only transversely but obliquely over some of their highest mountains, without material deviation from its normal direction, except along or near the bottoms of some of the valleys, in which cases the direction of the striæ nearly coincides with those of the valleys.

This coincidence of direction in the lower parts of the valleys is exactly what we should expect, and is accordant with the character of the like phænomena in Europe; and the persistency of transverse oblique directions in the striæ over the upper parts of elevated tracts presents no difficulty; for so long as the striating agent (as an iceberg) should only come in contact with those upper parts, its operations could not be influenced by the depths of the valleys below. But what takes place at intermediate heights between the bottoms of the valleys and the tops of the mountains? It is impossible to suppose, if the side of a mountain were striated in every part, that while the striæ at the bottom should be parallel to the lateral valley or axis of the mountain, and those at the top should be, for instance, perpendicular to it, the striæ at intermediate heights should not have some intermediate directions in passing from one extreme limit to the other. Careful observations ought to be made on this point. The height to which the striæ preserve their parallelism with the valleys below, and the distance from the tops of the higher ridges across which they preserve their transverse directions, should be most carefully noted. Nor ought any geologist, in a delicate question of this kind, to trust to vague measurements and general impressions. Every direction ought to be carefully taken and as carefully laid down on a good physical map, together with the dip and strike of the striated surface. The general configuration, too, of the immediate vicinity should be described, with reference to its probable influence on the motion of any mass to which the striæ may be attributable. Again, it has been said that in many cases the *lee side* and *storm side* of an elevated ridge are sometimes equally marked by striæ *transverse* to its direction. This seems entirely at variance with our observations on this side of the Atlantic, except in those cases in which the striæ are attributable to *local* action, in contradistinction to that more general action of such agents as masses of ice, for instance, driven in one direction over the whole region from N.W. to S.E. I have not hitherto been able to represent to myself the physical possibility of striæ on the lee side *remote from the top of the ridge*, having been produced by the general action just referred to. May they not have been more frequently due to local action than has been suspected? The glacial theories, on their first introduction, did not, I think, make so much impression on the minds of American as on those of European geologists, and many of the recorded observations of striated

rocks were made, if I mistake not, under impressions very unfavourable to those theories. Let me not be thought by this remark to cast a reflection on American geologists,—men to whom our science owes so much, and from whom it expects so much more in the noble field in which they are labouring; but we shall all do well, Gentlemen, in learning to doubt the completeness of our observations on difficult and controverted points when made under the strong impressions of antecedent convictions. What I am especially anxious for, is to see the American geologists resuming their observations in all possible detail on this interesting subject, and with candid reference to the different physical causes to which smoothed and striated rocks have been attributed. There are few phænomena more likely to elucidate the mixed and perplexing operations of the period to which they must be referred. In northern Europe M. Sefström has set us an admirable example by his careful and exact manner of making his observations, and of mapping the results of them. There is still much room for following out similar observations in the Scandinavian regions. In our own islands, too, in Ireland, we have a field in which much yet remains to be done. The observations on these points by my friend Mr. Griffith were made, as he has told me, a considerable time ago, and incidentally rather than as forming a leading object in his researches. It is not therefore to be expected that they should be sufficient to satisfy the present requirements of the science. If by these remarks, Gentlemen, I should perchance lead any geologist to reflect on the geological importance of this subject, and to make and record his observations upon it with more than ordinary accuracy, I feel that I shall be attaining one of the best objects for the accomplishment of which an address of this kind may be rendered useful.

I shall now proceed to make a few observations on the arrangement of the materials which constitute the Drift of northern Europe. Though in many cases this arrangement seems very confused, as we might expect it to be, there does appear to be frequently a decided predominance of finer material in the lower, and of coarser material in the upper portion. The lower mass frequently consists of fine argillaceous and arenaceous sediment, sometimes mixed with rolled pebbles, and reposing immediately on the polished and striated rocks. Taking the whole area of deposition in Norway, Denmark, Sweden, northern Russia, and northern Germany, the materials above described constitute the great mass of the drift; and on this mass generally the large erratic blocks are superincumbent, though many blocks are also found imbedded within its mass. The submarine origin of the general mass is rendered unequivocal by the organic remains which it is found in various localities to contain.

The boundary of the area over which this enormous mass of detrital matter has been deposited proceeds from a point E. of the White Sea towards the S.E. until it touches in one point only on the Ural Mountains, whence it proceeds south of Moscow to the Carpathian Mountains, and includes the whole of northern Germany. Throughout Russia and Poland it is laid down in the map which ac-

companies the 'Geology of Russia.' Independently of its zigzag irregularities, it may be considered approximately as the circumference of a circle having its centre near the northern extremity of the Gulf of Bothnia. A very large majority of the blocks dispersed over this immense area can be distinctly referred to their Scandinavian origin, thus showing in a remarkable manner the centrifugal or radiating action already mentioned of the forces by which this dispersion has been effected.

The granite-boulders seem to have been in this, as in so many other cases, the best travellers. They constitute the greater part of the blocks in the external zone of the drift. But it is of more importance to remark, that whatever may be the nature of the blocks, they become almost universally smaller and more rounded as we approach the external boundary above indicated. This seems to me conclusive as to the nature of the transporting agency in this outer zone. I can conceive water alone to be capable of giving these characters to the transported materials. On the contrary, as we approach the central portion of this region of drift, we find the blocks of enormous size, perfectly angular, and not unfrequently imbedded in masses of fine drift, indicative of the absence, at the time of its deposition, of any violent currents capable of moving the blocks imbedded in it. In this we recognize the transport by floating ice. And again, on the central land, we recognize glaciers as the source of the floating ice, and the means of transporting large angular blocks from their original sites on the mountains to the level of the ocean.

You will not suppose, Gentlemen, that in stating these conclusions I regard myself as opening new views to you. My object is merely to present the subject to you in a general but compendious form, in the hope that I may thus lead you to contemplate its various points collectively, and to see how much they are brought into harmony with each other by a distinct recognition of the three causes above mentioned, and a due allotment of the varied phænomena of the drift to their respective modes of transport.

The authors of the 'Geology of Russia' consider the present boundary of the region of the drift in north-eastern Russia, as indicating the approximate boundary of the glacial sea in that region during the drift-period, and this conclusion appears to me perfectly legitimate. They also consider the low, flat lands of northern Asia to have been, about the same period, under the sea. In favour of this view, there appears to be the unequivocal, though not perhaps abundant, evidence of marine remains. There seems to be no evidence, however, of a submergence of this region approximating in depth to that of many parts of the European continent; the present low lands were probably covered only with shallow water. And hence we may conclude that northern Asia was in a state of comparative repose during the period of much greater oscillation, and probably of more frequent and comparatively violent disturbance of the European area. Again, no traces of former glaciers have been detected on the Ural Mountains, or on the projecting headlands which run out to the northward from the high lands of northern and central Asia. This

former absence of glaciers, during our glacial period, in a region now so much colder than Europe, appears at first sight a great anomaly. It presents, however, no real difficulty, because those very causes which I believe to have produced the glacial cold of Europe would necessarily diminish the cold of northern Asia, and more especially that portion of it immediately east of the Ural chain, as I have explained in my paper "On the Causes of Changes of Terrestrial Temperature." This effect would be due to the extension of the Atlantic Ocean to the eastward, so that the region of the Ural would become part of the western shores of the old continent, and would experience climatal influences similar, though far less in degree, to those now experienced in our own region. Hence what I have termed the *line of 32° F.* would be higher in north-western Asia than at present. On the other hand, the extension of the ocean to the eastward would lessen the great difference which now exists in northern Asia between the summer and winter temperatures; and on this account the height of the *snow-line* above the line of 32° would be diminished. Consequently the absolute height of the snow-line would be increased by the first cause and diminished by the second, and would probably be not very different from its present height, though it might possibly be somewhat less. Now, since the configuration of the mountains was probably very nearly the same at the glacial epoch as now, the existence of glaciers upon them would depend upon the height of the snow-line; and, that height not being materially altered, there is no more reason why glaciers should have existed there at the more remote than at the present epoch; and at present we know that there are none in the Ural chain as far as the 70th degree of latitude*, and none on the mountains of northern Asia descending nearly low enough to reach the level of the shallow sea, which we suppose to have covered the low lands of that region during the glacial period.

This former absence of glaciers, and the comparative repose of northern Asia during our glacial epoch are sufficient to account for what appears at first sight extremely anomalous—the fact, that while on the west of the Ural Mountains we have a district covered with enormous erratic blocks, there is scarcely a single block to be found on the east of that chain at any distance from its original site, the whole mass of detrital matter, too, being very small and principally referable to merely local causes.

I cannot quit this part of our subject without reminding you of the lucid manner in which the authors of the 'Geology of Russia' have pointed out how well the above state of northern Asia accords with the supposed existence of Mammoths during the glacial epoch, and how happily Sir Charles Lyell and Professor Owen explained the capabilities of those animals to sustain the hardships of a cold climate. But before the publication of Dove's map of isothermal lines, we had no adequate means of accurately estimating the effect of such conditions as those above assumed on the climate of north-western Asia. The extension of the Atlantic Ocean nearly to the foot of the Ural chain would heighten considerably the mean annual

* Geology of Russia.

temperature of the neighbouring land, especially if the height of that chain was lower than at present, as Sir R. Murchison supposes it to have been at the period in question. But the great effect would consist in the lessening of the enormous existing difference between the summer and winter temperatures already alluded to. The winter temperature would doubtless be very much moderated, and therefore any difficulty of conceiving how great pachyderms could exist through a Siberian winter is in a great degree removed. Again, a much more adequate reason is thus assigned for their subsequent disappearance from that region. The cause to which this fact has been attributed is an increase of cold arising from some additional elevation of the Ural chain, and a rise of the region in general to the amount of a few hundred feet. I believe it, however, to be certain that these causes alone could produce but little influence on the climate; but if we unite with them the withdrawal of the ocean from the Ural chain within its present limits, we have an adequate cause for changing the climate from one much more equable than at present to the extreme of a continental one; from a climate in which the mammoth might exist to one in which its existence during the winter would be no longer possible. This would seem to afford a very adequate cause for the disappearance of the mammoths from the Siberian region; why they should not still have sought a refuge in lands somewhat more southerly, which must still have been open to them, may be a question of more difficult solution.

With respect to the *order* of events connected with the glacial epoch, conclusions have sometimes been drawn which do not appear to me altogether warranted by the observed phænomena. The striated and polished rocks, as fixed rocks *in situ*, must necessarily be subjacent, where they exist, to the lowest beds of the drift, frequently consisting of fine argillaceous and arenaceous matter. It has been hence inferred that the process of striating and polishing these subjacent rocks must have been altogether anterior to the whole process of deposition of the finer matter, each of these processes occupying distinct and separate intervals of time. No one would, of course, suppose that the matter reposing on a given surface of striated rock could have been deposited there before that surface became striated; but the real question is, whether these two processes of striating and depositing were not going on simultaneously in the region generally, though not at absolutely the same points. If the striæ be due, as some geologists have supposed, to detrital matter driven by a rapid current, the two processes must of necessity have been simultaneous, the one where the current was most rapid, the other where it was less so. Or if we refer the striæ in the lower and flatter regions of the area of the drift to floating ice, how was it that the icebergs and the currents which impelled them onwards bore no detrital matter at that time, and so much at a subsequent time? I conceive the two processes to have gone on simultaneously. No agency for the production of striated and polished surfaces has ever yet been suggested which would not almost necessarily be accompanied with the transport, and consequently with the deposition of detrital matter. Cur-

rents and small icebergs might deposit from time to time detrital matter on a given rock-surface, but the first iceberg that succeeded, large enough to reach down to that surface and grind over it, would clear away the detritus previously deposited upon it, and smooth and striate the rock itself. This might be repeated for a long period of time, during which the process of striating the projecting surfaces might be contemporaneous with that of permanent deposition at points almost immediately contiguous, but at lower levels. Finally, supposing a continued subsidence of the general area, the projecting striated bosses would sink below the reach of the icebergs, and the transport of matter still continuing, would become permanently covered up. As the general area re-emerged it would be subject to denudation, which might be expected to lay bare again some of the striated rocks, and leave others permanently covered with detrital matter as we now find them.

Again, with reference to the combined operations of floating ice and currents, it is not unworthy of remark that the former would necessarily deposit least of its freight, *cæteris paribus*, in its unimpeded motion over deeper waters, and a greater part in its impeded course over shallow bottoms. On the contrary, currents would deposit least on the shallow bottoms, where, *cæteris paribus*, their velocity would be greatest, and most in the deeper waters; and moreover it would be in these deeper waters that the finer matter would be deposited. Thus the existence of beds of finer and in many cases stratified deposits, having more tumultuous deposits possibly both above and below them, as in some parts of North America, does not necessarily indicate a cessation in the more energetic action of the forces of dispersion, but may merely indicate deposition in a deeper sea. If also large angular blocks from distant sites should be imbedded in this mass of finer matter, we see an additional indication of a deep sea in which a floating iceberg would, perhaps at distant intervals, drop a portion of its freight.

There is also a consideration connected with the process of transport by certain currents alone, which, with reference to our inferences as to the succession of events, is of some importance. I have mentioned it in my memoir "On the Granitic Blocks of the South Highlands of Scotland," which appears in the last Number of our Journal. Currents attending waves produced by sudden elevations, greater or less, are necessarily *transitory*, and each can only carry the materials it may transport to certain distances, depending, *cæteris paribus*, on the magnitudes of the component individual masses, the large blocks being carried but to small distances, and the smaller particles to much greater distances. Thus the first wave would produce a layer consisting of the larger blocks near their source, and of fine detritus at the remoter distances. The second wave would produce a similar effect, and would also carry the blocks of the first wave to a somewhat greater distance, and so on for successive waves. The effect, then, of a succession of similar waves would be the formation, over the more remote parts of the area of deposition, of a bed of finer matter, in the *upper portion* of which would exist blocks rounded

and waterworn by their transit. Thus we should have the phænomena of fine detrital mater below and blocks above, apparently referable to separate successive periods of time, during the first of which one kind of agency should have transported the finer sediment, and during the second another and much more powerful agency should have transported the blocks and coarser detritus, while, in fact, the whole phænomena would be really referable to a repetition of precisely the same agency during the whole period of transport. That period, therefore, except in a limited sense, and not with reference to the whole area of transport, could not, in the case now supposed, be divided into two, but must be regarded as one single period.

I do not mean here to assert the opinion that the actual glacial period recognized by geologists was characterized by a uniform succession of exactly similar events producing erratic dispersion. There might be particular portions of that period in which accidental circumstances produced a greater or less prevalence of each particular mode of transport; but I am satisfied that some of the attempts which have been made to subdivide the glacial period have been made without due regard to such considerations as those which I have given above.

Let us now turn again to the drift of North America. The American geologists appear for the most part to recognise three distinct periods into which the whole period of the drift may be divided. The first period was one of the transport of blocks and coarse materials; the second, one of tranquil deposition; and the third was again a period of transport of large blocks and coarser matter. This generalization appears to have been principally founded on the characters of the drift of Lake Champlain and that of the general valley of the St. Lawrence, where the beds of the second period not only consist, in great part, of finer matter, but are also, in many instances, distinctly stratified, and filled with organic remains. But before we can adopt these subdivisions of the general period with reference to so many distinct modes of action of the transporting agencies, or of the different degrees of intensity with which they acted, it will be necessary to prove the above-mentioned succession of beds to be *general* and not merely *local*. If local, I should be disposed to refer the tranquil deposition of the fossiliferous and associated beds, partly at least, to the condition of a deeper submergence than at the periods of the transport of the coarser beds and blocks above and below the finer beds. I see no reason in local facts of this kind to infer that there were three distinct periods with reference to the intensity or mode of action of the dispersing forces. I may here observe that Dr. Bigsby detected no evidence of this subdivision of the drift in the region which he examined further to the west.

Some of the American geologists appear to have entertained the opinion that the Mastodon existed in that region after the latest period of the Drift, and seem to refer its final destruction to some upheaval of the American continent. It may be doubted, however, whether any evidence has been offered of the existence of that animal

later than the latest drift in which its remains are found; nor do I understand how the cause just assigned could effect its final extinction. If, however, we admit the submergence of that continent to the extent which many geologists are now disposed to admit, there can be no difficulty in explaining the extinction of any of the great pachyderms which might have previously inhabited that region.

Without dwelling further on the characters of the Drift of this region, or on the minor details of the general phænomena of accumulations of drifted materials, I will proceed to give a short analysis of Dr. Bigsby's paper, to which I have already alluded, "On the Erratics of Canada." It is composed from notes made by the author several years ago, a circumstance to which the want of more frequent observations on polished and striated rocks must be attributed. The importance of those phænomena was not then recognized. The author, however, has been enabled by his general knowledge of the physical geography and geological structure of this region, and by a careful observation of the erratic materials, to make valuable additions to our previous knowledge of the Drift, derived from American geologists. His observations extend much farther to the north and west than those of the latter observers, as is best seen by a glance at the map which accompanies the memoir.

The author commences his observations at the Lake of the Woods lying to the north-west of Lake Superior. He then proceeds eastward successively to the lakes La Pluie, Superior, Huron, Erie, and Ontario, describing the rock-formations and the blocks, and other detritus which line their shores, and the banks of the streams connecting them. The water from Lake La Pluie runs westward and ultimately discharges itself into the Arctic Sea, while that from Lake Superior runs eastward to the Atlantic. The watershed between them rises to the height of about 1200 feet above the sea-level. In this tract are numbers of large erratics, which Dr. Bigsby was generally able to identify with rocks existing *in situ* to the north, but never on the south.

Lake Superior is about 600 feet above the level of the sea. On its northern shore are a considerable number of erratic blocks which have come from north and north-east. Such is the case also with the numerous large blocks on the banks of the St. Mary River which connects Lake Superior and Lake Huron. On the banks of Lake Superior are many *terraces* consisting of detrital matter derived for the most part from neighbouring rocks. The most important of these is that about the mouth of Black River, and rises to the height of 330 feet above the lake, extending far along the banks of the lake, and intervening between the neighbouring hills for several miles to the foot of an elevated range. Its mass consists of coarse unstratified native detritus imbedded in sand. Assuming the sea to have risen above this level during the glacial period, the masses now forming terraces of this kind must be considered as submarine deposits formed under comparatively tranquil conditions, the present lake-basins having been scooped out of them by denuding agents during or after their emergence from beneath the surface of the ocean.

Some islands on the north coast of this lake are described as strikingly *moutonnée*.

On Lake Huron the erratics abound, especially on the north side, where the hard rocks are much striated and rounded. We need not wonder that in 1824, their appearances were great mysteries to the author. It appears singular that there should be no terraces in this lake (so far as the author's observation extended), while there are so many in Lake Superior. The difference of level of the two lakes is only about 20 feet. This shows an irregularity either in the process of deposition or of subsequent denudation, which would seem to indicate an action far less gradual and uniform than ordinary diurnal action.

On the east of Lake Huron, near to Lake Simcoe, the river Notawasaga cuts through two remarkable freshwater beds filled with *Uniones* associated with many small freshwater univalves, as *Planorbes, Physæ, Lymnææ, Melaniæ, Paludinæ*, &c., all abundant in the river at the present day. There are two of these beds, each from 4 to 6 inches thick, and above are stratified beds of which the whole thickness in some places is not less than 150 feet.

Lake Erie is situated in the lowest part of the extensive tract south of Lake Huron. This tract is formed of widely-extended beds of blue and red clays with superincumbent beds of sand, which form the shores of Lake Erie, forming banks and scarps of considerable elevation throughout a distance, on the north shore, of nearly 300 miles. The erratics are principally from Lake Huron. The more level as well as the more distant erratics appear in all the lakes to have travelled more or less in a southerly direction, indicating clearly the wide generality of the principal cause to which the whole transport is referable.

Lake Ontario is about 330 feet below the level of Lake Erie, the Falls of Niagara, it will be recollected, being between the two lakes. Several lofty ridges or terraces wander round this lake at different distances, leaving a wide opening for the escape of its waters at its north-eastern extremity. The shores of the lake are, in many parts, formed of cliffs, sometimes 300 feet high (as near Toronto), of detrital matter, in some cases coarse, in others finer and stratified, and frequently containing erratic boulders. Many large erratics also exist on the surface.

In discussing these different phænomena, the author divides the whole detrital mass into *loose detritus*, and *imbedded detritus*. The former he again subdivides into

1. Distant Erratics;
2. Near or Lake Erratics;
3. Native Debris.

The prevalent courses of the distant erratics are southerly, but, as is seen by the appended map, they vary from south-east to south-west. I have already stated, that in the north of Europe blocks setting out from a given point do not all proceed in the same direction, but that the angle included between the extreme directions of radiation is a considerable one, sometimes even larger than a right angle. The va-

riation of direction above-mentioned may probably indicate a similar law of divergency from the original sites of the blocks. In one instance in particular Dr. Bigsby has shown this to be the case. He was able to trace the well-marked augitic trap of Montreal up the St. Lawrence to a point on the south shore of Lake Ontario, distant 270 miles from Montreal to the south-west. At the same time this rock had been carried southward to the tract about Lake Champlain, in much greater quantity. The angle between the extreme lines of radiation from this point must be at least 50°.

The distant erratics are not uniformly spread over the area of the Drift, there being in some places comparatively few. They are generally abundant in the higher localities, such as the top of Cape Tourment, Lower Canada, 2100 feet above the sea; on the summit of Montreal Hill, and on the high mainland north of Lake Superior. But they exist in the greatest number along the courses of most of the Canadian rivers at all the points where the configuration of the land is such as to oppose the greatest impediments to their transport along the river-valleys. This clearly indicates the operation of strong currents and floating river-ice in again transporting such blocks from the places in which they were first deposited by some more general agency.

The near or Lake erratics may be due in a considerable degree to existing causes, and not unfrequently radiate from the parent rock in different directions. In other cases, however, their prevalent southerly direction of transport and their numbers indicate the action of some more general and energetic cause. In the Lake of the Woods, for instance, the author remarks that, though the current is from south to north, it brings none of the loose masses of limestone at the south end of the lake to the shores of the northern end; while innumerable blocks from the latter end of the lake have been carried to its southern extremity. The author also remarked several piles of angular blocks which he conceives to be due to recent action, having been probably left there on shallows on which floating ice had stranded during the spring-freshets.

The author describes the Canadas and the northern and western parts of the United States as characterized by terraces and ridges which form a prominent feature in the configuration of the surface. They fringe the hills and define the hollow spaces, and in the more open country stretch out into elevated plains or low and swampy surfaces. They are generally formed of native gritty debris, but also contain foreign materials. The deposition of this general detrital mass is obviously referable to the period of submersion of this region, and the formation of the terraces to the denudation which accompanied the subsequent rise of the land. These effects of denudation naturally lead to the idea that the osars of Sweden and the eskers of Ireland may probably be due to a similar cause.

In connexion with these beds it is important to state that Dr. Bigsby was unable to recognize any indication of two distinct erratic periods, separated by a period of repose, which I have already spoken of as the opinion of some American geologists. This appears to justify

the idea which I have above suggested, that the phænomena on which such an opinion has been founded are only local.

Finally, the author states the localities of the freshwater beds which had been observed by himself and others. There are beds of this kind on the east shore of Lake Huron 614 feet above the sea, and others on the River Detroit, Lake Erie, and the River Niagara, at nearly the same elevation. On the Ottawa are many deposits of freshwater shells extending over a large area. Beds containing marine shells also range with them side by side. In Montreal Hill there are also marine shells 470 feet above the sea, while about a mile to the south there are freshwater beds at a level lower by some hundred feet.

The general explanation of phænomena of this kind does not appear to me to present any serious difficulty, according to the general views which I have expounded above. How far the striæ and the lines of dispersion may be generally characterized by the law of divergency from a general central region, or may be more partially characterized by divergency from particular centres, especially in the more northern parts of the continent, are questions which can only be answered by a far more detailed examination of the region lying to the north of the great chain of lakes. Meanwhile we gladly accept this paper of Dr. Bigsby's as a valuable addition to our knowledge of the details of the erratic phænomena of the district which he has examined.

Another paper on the subject of Drift and Boulders associated with it has been brought before us by Professor Ramsay. It is entitled, "On the Sequence of Events during the Glacial Epoch, as evinced by the Superficial Accumulations of North Wales." It will be recollected that many years ago Mr. Trimmer made the important discovery of marine shells in the Drift of Moel Tryfan at the height of 1392 feet. These beds Professor Ramsay states to be continuous on the seaward side of the mountain-range of Carnarvonshire. Between Cwm Seiont and Llyn Padarn, there is a moorland tract covered with drift in which the author found fragments of shells at the height of about 1000 feet. Between Llanberris and Nant-Francon there is also a broad moor covered with a great thickness of drift, stretching northwards along the left bank of the Ogwen, and eastward into the valley of Marchlyn Mawr, where it attains an elevation of 2000 feet. Corresponding accumulations also rise on the opposite banks of the Ogwen into the recesses of Carnedd Dafy and Carnedd Llewelyn, on their seaward flanks, in some places to the elevation of 2300 feet. Patches of similar drift also exist at equal altitudes at other points along this range of mountains. The large blocks rest upon or are imbedded in the smaller drift, and form, near the base of the mountains, a great portion of the whole accumulated mass. They do not appear, however, to have travelled from this range into Anglesea, where, so far as the author observed, the blocks are entirely of local origin. Very large insulated boulders are sometimes found also on the tops or sides of hills.

Those portions of what is here described as Drift in the higher lo-

calities, so far as they have been previously observed, have usually been regarded as moraines; but Professor Ramsay considers, and it appears to me with great reason, that the continuity of the whole accumulated mass with the shell-bearing portions of it constitutes a strong argument in favour of its entire submarine origin. This view appears also to be confirmed by the existence of large blocks, which have travelled considerable distances, now resting on the tops or sides of mountains, as above stated, at the altitude of 2000 feet. We shall most of us probably agree entirely with the author in the validity of this reasoning.

Professor Ramsay also recognizes moraines at considerable elevations above the sea, but much lower than the greatest height to which the Drift attains. Coupling this fact with the conclusion of the preceding paragraph, he expresses his belief that there must have been two glacial epochs in this region, the first preceding the deposition of the Drift; the second, posterior to that deposition, producing glaciers on a much smaller scale. "For," says the author, "if the loose moraines of Cwm Idwal" (which he has previously described) "had been formed during the *great glacier* period, they would either, in all probability, have been destroyed during the depression and re-elevation of the land which followed that period, or they would have been covered over and smothered in the succeeding drift."

This reasoning will not perhaps be deemed equally satisfactory with that by which the author establishes his conclusion respecting the depth to which the land of this region was submerged during the period of the Drift; but I am still disposed to think his conclusion to be so far correct, that these moraines (assuming them to be such) were formed after the re-elevation of the land from its lowest position of submergence. I cannot, however, agree with the author in admitting the evidence of *two* distinct glacier-periods. He would ascribe the glaciers of his first period to an enormous elevation of the whole region, and those of his second period to some peculiar conditions after the intervening submergence. I must of course feel myself bound, in consistency with what I have recently brought before you on the possible causes of changes of climatal conditions, to express my dissent from any theory that should assign a great elevation to Western Europe as an essential condition for the former existence of glaciers there. Their existence in Wales, both before and after the actual transport of those accumulations properly termed *Drift*, is just as well accounted for independently of any great upheaval of this region, and without the hypothesis of a discontinuity in the glacier-period. We have only to suppose glaciers to have first resulted from the cold caused by the diversion of the Gulf-stream into some other channel, and the submergence of a great portion of Europe; then a deeper submergence which left not more perhaps than one-third of Snowdon extant above the waters; and finally an emergence of the land to an elevation which should allow of glaciers descending to the points where the above-mentioned moraines are now observed. The depression of the land *might* be such as to bring the tops of the particular mountains we are now speaking of below the snow-line, and

consequently to prevent the formation of glaciers upon them; but there is nothing in the facts observed to justify this conclusion as a necessary one. And even if it were so, a merely local circumstance of this kind could scarcely justify the notion of two distinct glacier-periods without a guarded limitation of the expression as one of merely local signification. I throw out this caution lest the language of the author should lead to interpretations more general than the observed facts might justify, or than the author himself may possibly have intended. The facts described in this paper have been reviewed and confirmed, I believe, since it was read, and, as proceeding from so able an observer as Professor Ramsay, have been thought far too important to be omitted in this discussion, although they have not yet appeared in a printed form.

There is another class of superficial deposits, entirely different from those of which I have hitherto been speaking, and to which Mr. Austen has especially directed our attention*,—I mean the subaërial accumulations formed by the descent of disintegrated portions of rock which fall from the higher parts of the steep escarpment of a cliff or mountain, and collect at its bottom or along its face. Superficial portions of rock-masses, disintegrated *in situ*, may frequently also be associated with the accumulations just spoken of, the only difference being that, in the one case, the disintegration takes place in localities from which the disintegrated masses necessarily fall by their own weight, or by the action of the elements; and in the other case, those causes are not sufficient to detach them from their original positions. Mr. Austen has not only described the beds which he considers to belong to this class on the coast of the English Channel, but he also makes them subservient to the determination of the oscillations of level which he considers to have taken place along that and the adjoining coasts.

The last coast-line antecedent to the existing one, as recognized by the author, is about 8 or 10 feet higher than the latter. The next line, in backward order of time, is about twice as high as the first above the present level, estimating them all as high-water levels. These two ancient sea-lines, therefore, indicate two successive *elevations* of the land of about the same amount. A third sea-line is again recognized at nearly the same elevation as the first of the two above-mentioned. Taking the events in the reverse of the above order, or the proper order of time, we have

(1.) A sea-beach, when the land was *lower* than at present, by a variable amount in different places, sometimes amounting to 60 or 70 feet. This is indicated by a marine bed which was formed at that level.

(2.) A subaërial bed of shingle was then formed over this marine bed, by the disintegration and fall of the rocks immediately above it.

(3.) The land was *depressed* about 8 or 10 feet, and a thin marine bed was formed on the subaërial bed of shingle.

(4.) The land was *elevated* into a position a little higher than that

* Quarterly Journal, May 1851, p. 118, "On the Superficial Accumulations of the Coasts of the English Channel, and the changes they indicate."

it first occupied, leaving more or less of a platform at that elevation, bounded by a cliff of the aërial bed of shingle.

(5.) The land was elevated to its present position.

The marine bed mentioned in (1) consists of coarse marine gravels, shingle, and sand. The author recognizes it on many parts of the coast of Devon and Cornwall, and also considers the lower sand and shingle extending from Brighton to Rottingdean, as belonging to it. He also traces evidences of the other two beds at various points of the south coast of this country, and of the Channel Islands.

In developing his theoretical views, founded on the facts above stated, the author assumes the deposition of the oldest of the marine beds above mentioned as contemporaneous with that of the Norwich or Mammaliferous Crag. After this came the aggregation of the superincumbent bed of shingle above described as subaërial. But for the disintegration in which he conceives this aggregation to have originated, he considers a much greater intensity of cold to be necessary than could consist with the present position of the land, and is hence led to the opinion that those districts where the above beds exist must at the time of their formation have had "*an elevation of great amount, such as would place the whole of the higher portions of this country in regions of excessive cold.*" The author also states that "his view is quite distinct from the popular one, subsequently proposed by M. Agassiz, of a 'period of cold' or 'glacial period.'" What relation he supposes it to have borne to that period he does not, I think, distinctly explain. All the minor details of his views depend on the conclusions that the shingle-bed is subaërial, and that it could only be produced by a great elevation of the land above its present level.

The masses of sharp shingly stones described by Mr. Austen, and their local character, entirely agree with his opinion as to their origin; but it should be borne in mind that they might have these characters without being subaërial. An example will be found in a paper of which I shall have shortly to speak, by Mr. Prestwich, of an aggregation very similar to the above-mentioned beds so far as regards the character of its materials, but of which the origin is unquestionably subaqueous. The first manifest test to be applied to such beds to determine whether they are subaërial, is to compare the distance to which they extend from the foot of the cliff or hill from which they may have fallen, with the height of the cliff or hill itself. If that distance should exceed two or three times the height of the cliff, it would be, I conceive, extremely improbable that the general mass could have been aggregated from the falling of disintegrated materials by their own weight. No intensity of the disintegrating power could meet this difficulty. Mr. Austen has not given us the means of applying this test; but I am sure that he will feel that geologists have a right to demand it before they adopt his conclusions on this point as the foundation of the further theoretical views which he has made to rest almost entirely upon them. I allude to his assumed enormous elevation, at a former though recent geological epoch, of the regions in which these beds are found, and of which their existence

is alleged as the principal proof. To many geologists the foundation will possibly appear small for the superstructure raised upon it.

Mr. Austen has not stated the height to which he supposes the south coast of this country to have been elevated during his cold period, but he appears, I think, to intimate by a reference to the soundings of 200 fathoms' which are found at no great distance in the Atlantic, that an elevation not much exceeding that amount might give us in this country a permanent snow-line. I have shown, however, in a memoir lately read, that a very much greater elevation would be necessary for that purpose, and I have there fully explained my reasons for believing that the cold of the Pleistocene period was not produced by an elevation of the land, but by entirely different causes. The author, therefore, will not be surprised to find me unprepared to accept many of the theoretical views put forward in this paper, and for which I must refer you to the paper itself. The questions arising from changes of climatal conditions, and the physical causes of those changes, are of great difficulty, and, however imperfectly I may have discussed the subject myself, I have shown at least that there are many essential considerations connected with it, to which the author of the present paper makes no allusion. At the same time the facts brought forward are entitled to the same consideration as other facts, so far as they bear upon the subject; and for the careful observation and arrangement of those facts, we must all feel our obligation to Mr. Austen.

I have already alluded to an accumulation of angular materials observed by Mr. Prestwich, and very similar in character to those described by Mr. Austen. It is described in his paper "On the Drift of Sangatte Cliffs near Calais." It resembles also the similar accumulation at Brighton, described long since by Dr. Mantell. The whole mass abuts against an old chalk cliff 80 feet high, rising to the same height on the face of the cliff, and thinning off in receding from it. The lowest part consists of a bed of rolled water-worn flints, marking the former existence of a sea-beach exactly analogous to that at Brighton beneath the Elephant-bed. The mass immediately superincumbent on this bed consists of a coarse mixture of sand, clay, and chalk, containing a few unrolled flints, and some irregular patches and layers of flint-gravel. The whole of this part of the mass is about 50 or 60 feet thick, and above it, but without any distinct separation, is a mass of angular flint-gravel, 20 or 25 feet in thickness. It contains also a small quantity of materials derived from the ruins of the former tertiary strata of the district. The whole appears to be chiefly of local origin.

The author considers this accumulation of Drift to have been comparatively rapid and tumultuous, nor can I recognize the slightest ground of dissent from this opinion. The distance to which the mass extends from the old chalk cliff against which it abuts, excludes the possibility of its being referred to the cause to which Mr. Austen, as already stated, refers certain smaller accumulations of similar materials on the south coast of this country. The analogy between this case and that of the Elephant-bed and subjacent pebble-bed at Brigh-

ton, appears to be perfect, with the exception that no organic remains have yet been detected in Drift of Sangatte.

I have now to direct your attention to an elaborate paper, "On the Distribution of the Flint Drift of the South-east of England," by Sir Roderick Murchison.

In the first place the author makes the important remark, that the central ridge of the district, consisting principally of Hastings Sands, is entirely devoid of drift, and of the remains of the great land animals which are found in it in other localities. On the southern side of the ridge, on the contrary, the Weald Clay and Lower Greensand are frequently covered with Flint Drift, extending from Petersfield eastward to the coast; forming a continuous layer over considerable surfaces, but in others more or less interrupted. It is also to be remarked, as a curious circumstance, that this Drift does not, unless in a few insulated patches, extend over the Gault, Upper Greensand, and Lower Chalk, to the foot of the Chalk-escarpment. Westward it can be traced to the confluence of the North and South Downs, near East Meon on the west of Petersfield. At that extremity it consists of flints, but more eastward about Trotton Common, hard pieces of Iron-stone and Chert, from the Lower Greensand, are added to it. The flints are splintered, sharp, and unworn. As we approach the eastern extremity of this zone of Drift near Eastbourne, it contains a large quantity of loam and clay. It is in these portions of the mass that the remains of extinct mammalia are principally found. The greatest height to which the Drift here attains is on Rogate Common about 500 feet above the sea.

The author considers the flints of this mass to have been derived from the Chalk, west of Petersfield, from whence they have been carried eastward by a powerful current, the tract having been previously submerged to the required depth beneath the sea. He thinks they cannot have been derived from the parallel Chalk-escarpment of the South Downs, on account of their absence in the intervening zone of Gault and Upper Greensand. Admitting, however, the easterly course of the transporting current, it would seem still very difficult to understand why the flints should not have been spread by it over the Gault in the lower part of the valley along the foot of the Chalk-escarpment, which must have directed the course of the current. It would seem to me more probable that the lower zone along the Gault might be left under water while the higher zone of the Lower Greensand along which the Flint Drift is now distributed was, soon after the deposition of the Drift, elevated into dry land. In such case the ordinary denuding action of the sea, aided probably by currents of elevation, might again denude the Gault of its superincumbent Drift. According to this hypothesis, it would not be necessary to adopt the author's notion that all the flint-debris has been derived from the Chalk at its western extremity. It may have come in part from the neighbouring escarpment. But from whatever source it may have been derived, I entirely concur with the author in believing that angular flints, often as sharp as gun-flints, could not have been deposited in the state in which we now find them, by the ordinary

tidal and diurnal action of the sea. If the form of these sharp angular flints is not to be received as the evidence of the action of a transitory agent, in contradistinction to that of the ordinary action of the sea, I know of no evidence or reasoning on the subject worthy of our acceptance.

In the author's discussion of the Drift phænomena on the southern slope of the South Downs, the Elephant Bed at Brighton occupies, of course, a prominent place. He regards the bed of rounded shingle, subjacent to the bed of angular materials which constitutes the Elephant Bed, as a true ancient beach, a point on which all geologists, I presume, are agreed; but he differs entirely from those who regard the superincumbent bed as due to any long-continued action of the sea, similar to that which rounded the pebbles of the bed beneath. In this view, I cannot but consider him fully justified, by the difference in the character of the materials forming these beds respectively. He also equally disagrees with those who would refer this bed of angular flints to the cause to which Mr. Austen has directed our attention, with reference to certain other cases, the mere descent of materials dislodged from the heights above; and for this view he assigns an adequate reason in the extent to which this accumulation can be traced; for as I have already remarked, aggregations so formed cannot possibly extend beyond a very limited distance from the foot of the eminence from which they fall.

In the south-western part of the district, from the slopes of Goodwood, by Chichester, to the foot of Portsdown Hill and Portsmouth, there is a large mass of detrital matter, including clay and sand mixed up with *angular* chalk-flints, but in no case, the author states, are *rolled* pebbles included in it. Again, we find the same angular-flint breccia, only that the proportion of flints is smaller, about Bognor and Little Hampton. One mass, however, of rounded pebbles exists at Clapham Common, half a mile east of Patcham, but the author refers it to the pebble-beds of the plastic clay.

Following the Chalk-escarpment on the west, the author describes it as entirely denuded of flints (as are also the surfaces of the Upper Greensand and Gault), while considerable quantities of them are found on the Lower Greensand. The distribution here is similar to that of the flint-detritus, already described, along the escarpment of the South Downs, and Sir Roderick considers them as probably derived from the same origin near Petersfield. Proceeding northward, however, to the high central ridge of Lower Greensand about Hind-Head, the flints entirely disappear, until we advance still farther northward towards Farnham and the escarpment of the Hog's Back, where much debris is again found on each side of the River Wey. In this north-western angle of the denuded district, the flints, broken and angular, are spread out in great quantities, not only on the Lower Greensand, but also over the Gault on the broad plateau of Alice Holt, and extend continuously (as the author believes) to the north of Farnham, over the Tertiary beds, and, on the other hand, for three or four miles eastward along either bank of the Wey, where fossil mammalia have been found.

Further to the east, the depression of Peasemarsh has been filled with detrital matter, similar to the above, according to the author's statement, with the exception of an admixture of flints somewhat abraded. He conceives, in opposition to the views of Mr. Austen, that the gravel was not collected here when Peasemarsh was an estuary*, but is referable to the same general cause as the flint-gravels in other localities. A similar depression occurs near Dorking, occupied also by Drift, which contains, however, fewer flints and a much larger proportion of loam. This depression is opposite the chasm in the Chalk, through which the river Mole makes its way, as Peasemarsh is opposite a similar chasm which makes a passage for the Wey. In this region also the Drift is accumulated at several points on the Weald Clay. The most remarkable accumulation of this kind is that at Hever, on the verge of the Medway valley, at an elevation of 60 or 80 feet above the river. It contains flints, principally angular, and fragments of clinkers and cherts of the Greensand. It is about nine miles from the nearest part of the Chalk-escarpment. The author infers that the transporting currents must here have had directions *from* the Chalk-escarpment, since the flints, as you recede from them, become smaller and smaller. These currents must therefore have had directions opposite to those of the Darent and Medway.

At Dover and Folkstone there are cases of accumulations of Drift exactly analogous to that at Brighton. The author very justly insists on the importance of the *continuity* of the Drift in these places, from the masses in the coombes and hollows to the thinner layers which envelope the sides and tops of the surrounding hills. If this continuity be admitted, I can hardly conceive the possibility of this Drift being referable to any agency of which the mode of action was very different from that to which the author attributes it.

In the conclusion of this paper the author has entered into a somewhat detailed development of his views respecting the agencies by which he conceives the transport and deposition of the superficial masses of detritus to have been effected. It should be understood that the discussion of this question is independent in a great degree of the general denudation of the Weald, which must have been in a great measure completed before the operations here considered took place; and the movements, supposed by the author to have generated transporting waves, or to have produced faults like those which, according to Mr. Austen's statements, appear to have disturbed the detrital masses about Peasemarsh, must have been long posterior to those far greater movements which, in conjunction with subsequent denudation, gave to the district its present general configuration. Assuming then this antecedent configuration, the first question is—What was the general position of the district with reference to the sea-level? At a period immediately antecedent to the Drift of which we are speaking, this position is clearly indicated along a part of the southern coast, by the ancient pebble-beach at Brighton, subjacent to the

* See Mr. Austen's Paper "On the Gravel Beds of the Valley of the Wey," Quart. Journ. Geol. Soc., Nov. 1851, p. 278.

elephant-bed, and by the exactly corresponding bed at Sangatte, on the opposite coast. At the succeeding period there must have been a great depression, assuming the Drift to have been of submarine origin, since it is now found at elevations of several hundred feet above the sea-level. And this is in perfect accordance with the depression which must have taken place, as we believe, at the same period over a great portion of northern and central Europe. It would appear probable that the central ridge of the district, where the Drift is stated to be entirely wanting, was extant above the ocean, and possibly it might be the only part that was so. On this point the author does not appear, I think, to have been very explicit in the statement of his views. He conceives the transport to have been effected by waves of translation, but at the same time he states that "there can be little doubt in affirming, that neither during the operations which deposited the debris, nor after them, was the Weald valley occupied by the waters of a sea, or its transverse gorges by marine narrows*." Whence then came the transporting waves? The author would appear to have left this question open, and perhaps intentionally. The reasons for the opinion quoted above are, the absence of marine remains, of rounded pebbles, and of ancient beaches. These are important facts. It is essential that we examine carefully the extent of the inferences which they justify.

The absence of marine organic remains in a particular and limited region cannot be accepted, I conceive, as a conclusive proof of that region not having been submerged beneath the sea. In fact we know how few and limited are the localities, either in Europe or North America, in which the period of the Drift has left us recognizable marine organic remains, though their number and distribution are sufficient to prove beyond doubt the submergence of those regions during that period. The true inference from their absence, and from that of tranquilly stratified sedimentary beds, in a particular district, would seem to be, that during the Drift-period, the quiet process of sedimentary deposition was never allowed to proceed uninterruptedly for a sufficient length of time to admit of an accumulation of such sedimentary beds, too large to be swept away during a succeeding period of disturbance. The author's inference that there could have been no submergence at the period alluded to under a sea of ordinary tranquillity, appears to me valid as against the views which he combats; but his conclusion from the present argument, that there could be no submergence at all, I conceive to be altogether untenable.

Again, let us examine the conditions under which we might expect raised sea-beaches to be left, in consequence of the elevation of the land and consequent retreat of the sea-margin. Such old beaches may present themselves as ledges or terraces encircling higher grounds, like the Parallel Roads of Glenroy, or the frequent and extensive terraces of North America; or as mere beds of rounded shingle. Now let us suppose the elevation of any coast-line to take place instantaneously: the "raised beach" would doubtless be traceable with almost perfect continuity, by means of both the above cha-

* Quart. Journ. Geol. Soc. for February 1852, p. 393.

racters where the beach was shingly, or by the ledge or terrace alone, in the absence of shingle. In what cases then would this terrace-like feature be obliterated? In the first place, if the rise of the land were absolutely *continuous* for a great length of time, and therefore extremely slow, there would be no general cause for the formation of a terrace at all, for a terrace could only result generally from the land remaining a long time at the *same* level, and then being suddenly raised to another level. If the rise of the land were of sufficient magnitude to place the raised beach above high-water mark, the terrace might still be destroyed by the action of the sea, provided the land remained at the new level long enough for that action to wear away the new beach sufficiently to undermine the old one, and thus form, to a certain height, a new face to the cliff or higher land fronting the sea. The smaller the rise of the land, the sooner, of course, would the obliteration take place.

This mode, however, of obliterating raised beaches would evidently be much less effective in those cases in which the inclination of the surface of the land at the sea-margin should be small, than in those in which it should be comparatively large, and the same observation would also apply to the action of terrestrial and atmospheric causes. It would be difficult, for instance, to account, by means of the causes alone now mentioned, for the absence of all indications of former beaches on many of the sloping surfaces of the Wealden, unless we suppose the land, during its last emergence, to have risen much more continuously than it appears to have done along the southern coast; and even in that case the entire non-existence of rounded pebbles in the district would still, as Sir R. Murchison has contended, present a great difficulty, unless we can assign some more efficient cause for their removal. Their formation would, I conceive, in many places within the Wealden be the necessary result of coast-action.

The cause which I consider as adequate both for the removal of all rounded pebbles and for the obliteration of terraces, is that diluvial action to which our author refers the distribution of the small angular detritus of the district. This action I conceive to be that of waves of translation (as Sir Roderick also supposes) produced by earthquake movements frequently repeated, while the lower parts of the district were immersed at different depths beneath the surface of the ocean. These movements, however, were quite distinct from those which gave its geological configuration to this region, being probably referable, as already stated, to the same period as the smaller faults described by Mr. Austen in the neighbourhood of Peasemarsh, the latest period at which the district was under water. The magnitude of these movements need not alarm the most timid geologist. Assuming them to have been frequently repeated, it is certainly not essentially necessary to suppose them of much greater intensity than that of many earthquakes of modern times. It is necessary, however, to suppose this to have been the last aqueous agency effectively exercised in this district. It can not, according to this view, have been followed by any long-continued diurnal action of the sea. And this, I have reason to believe, is essentially what Sir R. Murchison contends for,

though it may scarcely seem consistent with the passage above quoted from his memoir, in which he might appear to exclude the water which was necessary as an agent of transport.

Mr. Martin has published in the Philosophical Magazine during the last year, an account of the phænomena of elevation and denudation of the district of the Wealden, which has since been printed in a separate form under the title "On the Anticlinal Line of the London and Hampshire Basins." The principal part of it was embodied in a memoir read before this Society Dec. 16, 1840, and which only failed by some accident to be published in our regular Proceedings. I rejoice that the author has repaired the loss to geology by thus printing his memoir. The value of local and detailed observations from so careful an observer, intimately acquainted with the district, cannot be too highly appreciated. In this paper Mr. Martin has described the Drift of the same district as that to which Sir R. Murchison's description applies. He separates it into four separate zones, as follows:—

1. Tertiary zone	Pebbles and broken shingle beds; slight admixture of angular flints; sand and loam, and some chalk-rubble.
2. Cretaceous zone ...	Angular flints; pebbles very rare; very little loam, but sometimes much chalk-rubble.
3. Subcretaceous zone	Angular flints with chert, ironstone, and sandstone; much sand and little loam.
4. Wealden zone.....	Iron rag (a conglomerate of the *debris* of the various beds above and below the Weald Clay). Beds of diluvial loam, sometimes of great depth.

The first two contain bones of mammals, and other Pleistocene remains; the third contains very few, and the fourth scarcely any at all.

This description is very similar to that given by Sir R. Murchison, though differently arranged. The first zone probably includes a somewhat wider range than that contemplated by the latter author, and therefore perhaps includes more of the tertiary pebbles. Sir Roderick has stated that there is a marked absence of flints over the surfaces of the Upper Greensand and Gault, especially along the foot of the escarpment of the South Downs. Mr. Martin has not recognized this fact. The tract would divide his Cretaceous and Subcretaceous zones. In the Wealden zone he seems to have recognized a greater extent of detrital matter than other geologists, in the existance of considerable beds of diluvial loam.

Mr. Martin's views respecting the general structure of the district are, in all essential points, in perfect accordance with my own, as brought before the Society some years ago. I was, in fact, indebted to him for most of the details of the phænomena in his own immediate neighbourhood; and a considerable portion of the contents of his present essay would have appeared in conjunction with my memoir, had it not been for the accidental omission already alluded

to. I am glad of this opportunity of doing justice to Mr. Martin's claims as an original and accurate observer of many of the geological phænomena of this district.

Mr. Martin's theoretical views respecting the denudation of the Wealden, are much more in accordance with those which were more prevalent some years ago than at the present time. He considers it to have been effected by the transporting power of a limited number of large waves, such as have been termed of late *waves of translation*, or *waves of elevation*, and not by the more tranquil and long-continued diurnal action of the sea. I confess myself to have no faith in either of these extreme theories, one of which would regard the denudation as almost entirely due to tumultuary action, and the other as produced almost solely by the ordinary present action of the sea. If the denudation was tumultuary, the simultaneous deposition of the transported mass must have also been tumultuary. But no tumultuary deposit equal in amount to a thousandth part of the mass, probably transported from this and the surrounding districts, now exists in their vicinity. If it ever did exist, how, it may be asked, has it disappeared except by that slow process of denudation which must synchronize with the equally slow process of deposition of sedimentary, stratified and fossiliferous beds; and if this latter process could be thus effective in again transporting the mass after its first tumultuary removal, why should it not have been effective in transporting a large portion of this mass from its original site? But, again, on the other hand, are we to assume that there has been no tumultuary action peculiar to periods of great disturbance and denudation? A few years ago only geologists were doubting whether the Drift in general was subaqueous or subaërial; but no one now doubts its being the former, and, that doubt being removed, I contend that the proof of tumultuary action afforded by what are considered drifted materials, is as conclusive as that of more tranquil action afforded by the fossiliferous beds of former periods. In fact it is by the character of the transported masses alone that we can judge of the energy of the agency which has removed them. To do otherwise must be to depart from the true spirit of inductive philosophy, and to base our theories upon unsupported hypotheses.

In the region of the Wealden we have little direct evidence of any action of violent intensity in the process by which it has been denuded. At the same time we have, as Sir R. Murchison has contended, distinct evidence in the characters of the superficial drift, of an action different from the daily action of the sea, and to a certain extent tumultuary. Had the process of denudation been continued, this coarser matter would doubtless in its turn have been comminuted and carried off possibly in the form of fine sediment. And further, if this more powerful action was produced in the last period of the denudation, how can we avoid the conclusion that a similar action must have been frequently repeated during the period in which all the principal phænomena of elevation throughout the district must have been produced? The conclusion appears to me inevitable. I conceive that by a repetition of such action, not necessarily of any

great intensity, the denudation of the district was probably much assisted, while a very large proportion of the transported matter was finally carried off in the form of fine sediment by the ordinary action of the sea. Without the aid of this repeated tumultuary action, I cannot, in fact, conceive how all traces of marine deposit and coast action could have so entirely disappeared from the valleys of the Wealden, those of the Highlands, or those of many other regions.

The Drift which has been described in the papers by Mr. Austen, Mr. Prestwich, Sir Roderick Murchison, and Mr. Martin differs greatly from a large part of the general mass of Drift derived from the north and spread over the wide areas of northern Europe and North America. The difference consists chiefly in the absence of large blocks, the generally unworn character of the constituent materials, and the local origin of the masses here spoken of. Certain portions of superficial masses of this kind, though in a geological view of little more importance than the rest, are now become of immense importance in an economic point of view, from the circumstance of their being *auriferous*. Two papers, by the Rev. W. B. Clarke and Sir R. I. Murchison, were read at one of our recent meetings on the subject of the auriferous Drift of Australia.

Mr. Clarke commenced his researches on the geology of the district west of Port Jackson in 1841, and soon observed indications, though very faint, of the existence of gold. Continuing his researches up to a recent period, his convictions became stronger, and were made public through the medium of several local journals, that Australia was an auriferous region of considerable promise. In 1847 he became for the first time acquainted, he says, with the views entertained by Sir R. Murchison respecting the true interpretation of the geological system of Australia, and obtained some knowledge of the auriferous deposits of the Ural Mountains, from the abstract of an account, given to the Geological Society of France by M. de Verneuil, of the researches made by Sir R. Murchison and himself in Russia. Mr. Clarke was thus enabled to institute a comparison between the phænomena of the Ural and those of Australia, which he published in the Sydney Herald of September 28, 1847.

In 1845 Sir R. Murchison and his associates published the 'Geology of Russia in Europe,' containing considerable details, as you will recollect, of the gold-bearing detritus of the Ural Mountains, and of its geological relations to the neighbouring rocks. These rocks consist in great part of various schistose quartzose masses, with granites, porphyries, and injected igneous rocks, such as generally characterize the axes of mountains belonging to the oldest geological periods in other places; and the auriferous detritus consists of the local debris from these mountainous masses. From this debris nearly the whole of the gold obtained from the Ural Mountains is extracted, very few of the veins in the solid rock being found to yield any considerable quantity of ore. The recent geological date of the debris was also established, by the fact of the existence of bones of the mammoth imbedded in its lowest portions.

The geological characters and relations of this auriferous Drift

being thus clearly ascertained, Sir R. Murchison concluded that detrital accumulations having the same characters, and derived from similar ancient rock masses, in any other part of the world, might also be expected to be auriferous in a greater or less degree.

Just before his examination of the Ural chain, he had had an opportunity of examining some specimens of the rock masses brought by Count Strzelecki from the eastern part of Australia, and was thus able to recognize the identity of character presented by these rocks and those of the Ural. Hence he was led to the conclusion that the local detritus of what he termed the Cordilleras of Australia, ranging generally in a north and south direction, would be found to contain gold, as it was found in the Ural chain and the Cordilleras of America. In 1846 he expressed this opinion publicly to the geologists and miners of Cornwall, recommending such miners as might be in want of employment to emigrate to Australia, where, he assured them, they might expect to be well remunerated for their labour in a diligent search for gold. These remarks were subsequently embodied in a memoir, and published in the Transactions of the Royal Geological Society of Cornwall. Not long afterwards, his discourse in Cornwall, printed at the time in the local journals, appeared in the Sydney papers.

It appears, then, from the statements contained in the two papers before us, that both Sir R. Murchison and Mr. Clarke had been asserting the probability that Australia would be found to be an auriferous region, for some years previous to 1847. Up to that period their respective speculations, however, had been independent of each other, and evidently rested on totally different foundations. Sir Roderick's rested on an induction from a careful observation and extensive knowledge of the geological characters of known auriferous districts, applied to Australia, without any knowledge, up to the date just mentioned, of the actual discovery of gold in that country; for he does not appear to have known till a later period that Strzelecki had observed indications of gold near Bathurst several years before. On the other hand, Mr. Clarke's speculations were inferences from the facts that minute quantities of gold had been actually discovered in different parts of the country, but were, up to the above date, unsupported by that more accurate knowledge of the geological phænomena of other auriferous districts, on which Sir R. Murchison had entirely founded his speculations. In the one case we have the generalization of the geologist, in the other the simple inference of the observer.

Subsequently, in 1847, Mr. Clarke's views became strengthened by his obtaining some knowledge, as already stated, of the auriferous deposits of the Ural Mountains, and the views of the authors of the 'Geology of Russia' on the subject; and in 1848 Sir R. Murchison's views were corroborated by his receiving a piece of gold which had been found in Australia by persons who were desirous of prosecuting further researches. His convictions on the subject then became so strong, that he thought proper to write to Lord Grey, as Colonial Secretary, stating to him that gold was likely to be found in Australia to an extent which might render it of immense importance to the in-

terests of the colony. Subsequently, also, he detailed his views on the subject at the meeting of the British Association in 1849, and on other occasions.

Lord Grey, it appears, was of opinion that the discovery of gold in Australia would only be productive of ill effects by deranging all the internal existing relations of the colony; but had his Lordship felt that confidence to which a prediction founded on such sound geological generalization and such strict analogy as that of Sir R. Murchison was entitled, an examination of the reputed auriferous beds would probably have been immediately instituted under agents of the government. The discoveries subsequently made would have been the necessary consequence; and preparatory arrangements for explorations might have prevented much of the evil which arose from the first announcement of the abundance of gold. It will be well if this should be accepted by our Government as another proof of the importance of a due attention to the suggestions of science. With this neglect on the part of the Government, the discovery of the real value of the Australian gold field was left to be made by Mr. Hargraves, who had acquired a knowledge of gold-digging in California. His experience enabled him to detect immediately the existence of gold in sufficient abundance to render workings for it profitable.

After this announcement Mr. Clarke published a letter in the Sydney Morning Herald of May 29, 1851, the contents of which are nearly the same as those of the paper recently read before the Society. It was also widely circulated in this country through the medium of *The Times* newspaper. There is, however, a difference between the letter and the memoir which I think it right to notice. In the latter there are ample references to Sir R. Murchison and others, whereas in the former there are no such references at all, so that the perusal of it might produce the impression that the author not only claims the merit of having inferred from his own observations in Australia, or those of others, the existence of gold in that region, but also the merit of a wide generalization and induction founded on a comparison between the geological phænomena of Australia with those of other gold-bearing regions, especially that of the Ural. Now this is precisely what Sir R. Murchison had done, and to him alone the merit of this generalization, and of the prediction founded upon it, is unquestionably due. Had the author anticipated the extent to which this letter has been circulated through the medium of the Government Reports and of newspapers, he would have been, I doubt not, more careful to make due mention of the labours and speculations of others.

The district of Bathurst lies in a westerly direction from Sydney, the direct distance from that place to the town of Bathurst being about 100 miles. The latter town is situated on the River Macquarie. The valley through which the river takes its north-westerly course is several miles in width, and bounded on the south by a ridge of considerable elevation, consisting, like the other mountains of the district, of old schistose rocks traversed by veins or dykes of quartz. The alluvium which occupies the valley ascends also into the gullies and *creeks* about the foot of the range. It is in this alluvium that

the grains of gold are found, finer in places more remote from the mountains, and coarser in creeks at their base. In these latter localities the gold is generally most abundant. The first diggings were commenced in this range about 25 miles west of Bathurst. Gold has also been found in numerous other places. Mr. Clarke calculates that in this tract of the Macquarie alone it must extend over an area of 700 or 800 square miles; and this is doubtless but a small fraction of the area throughout which it may be expected to be found hereafter.

Other metals are usually found in greatest abundance in veins which are generally as rich at great depths as at the surface, and sometimes more so; but veins of gold, on the contrary, where they have been worked in the solid rock, have been invariably found to become poor at any considerable depth beneath the surface, so that the working of them is seldom remunerative. It is the comparative richness of the gold-veins near the surface which accounts for the existence of the metal in such abundance in the alluvium or Drift, the same agencies which deposited the drifted materials having also carried away the gold from the superficial portions of the veins in which it was originally found. In Australia we have only a repetition of the phænomena which have presented themselves in the Ural, California, and in every other locality where gold has been found in abundance.

The next paper to which I shall call your attention, although not directly on the subject of the Drift, may be considered as closely associated with it, one of its principal objects being to account for the peculiar climatal conditions of the glacial period—that period to which geologists now universally refer the general phænomena of Drift. I allude to the paper which I have myself brought recently before you, "On the Causes of Change in the Earth's Superficial Temperature." You will recollect that, until very recently, the only change of climate which had been recognized by geologists as having taken place during the earth's geological history was one from a higher to a lower temperature, and, for those who believed in the *primitive heat* of the globe, that heat afforded one obvious cause for this higher temperature at remote geological epochs. When, however, an examination of the phænomena of the glacial epoch rendered it necessary to recognize a change of climate in our own region of the globe from a lower temperature during that period to a higher subsequent temperature, new conditions were added to the problem which rendered the cause formerly assigned manifestly inadequate for its solution. Two other causes, however, had been previously suggested, which might possibly account, not only for a change from a higher to a lower superficial terrestrial temperature, but also for oscillatory changes. One of these assigned causes rested on the hypotheses of motion of the whole solar system in space, and the variable temperature of the different regions through which it might thus pass; the other cause assigned was the influence of different configurations of land and sea on the climatal state of particular portions of the earth's surface. Thus of the three causes above alluded to,

speaking of them with reference to the earth's surface, one was internal, another external, and the third superficial. No attempt, however, had been made to examine the efficiency of these different causes to account for all the phænomena which may be referable to them. It was to remedy this defect that I undertook the investigations contained in the paper of which I am speaking.

Assuming the primitive temperature of the globe to have been very much greater than at present, there is manifestly no difficulty in accounting for any higher superficial temperature than the present, at past epochs, provided those epochs be sufficiently remote. They must, however, be exceedingly remote to enable us thus to account for a variation of temperature which should sensibly affect the climatal conditions in any part of the earth. The terrestrial temperature, to the depth of about 70 feet, varies with the progress of the seasons, the variation becoming less as the depth is greater, until, at about the depth just mentioned, it is no longer sensible, so that a thermometer placed there would indicate a constant temperature during the whole year. A second thermometer at a greater depth would also indicate a constant temperature throughout the year, but higher than that indicated by the preceding one. If this second thermometer were placed at a still greater depth, it would indicate a still higher constant temperature; and the increase of temperature between the two thermometers would be proportional to the distance between them, i. e. the temperature in descending below the first thermometer would increase at a constant uniform rate.

Again, if the cooling of the earth were to continue for an indefinite period of time, assuming the temperature of external space, the sun, and the earth's atmosphere to remain as at present, the superficial temperature would approximate indefinitely near to a certain limit. The difference between that limit and the earth's present superficial temperature is the effect due to the remains of the primitive heat. Now theory gives us a simple relation between the amount of this effect and the rate of increase above-mentioned as we descend below the earth's surface*. Consequently, knowing the one, we can immediately determine the other, and thus, having ascertained the above rate of increase, we know the amount of superficial temperature which is now due to the earth's primæval heat, assuming always that heat to be the cause of the existing internal temperature of the globe. This amount is thus proved not to exceed about the $\frac{1}{30}$th of a centesimal degree, so nearly has the earth's superficial temperature approximated to that ultimate limit beyond which it could never descend, supposing external conditions to remain the same. It was calculated by Poisson that, to reduce the superficial temperature by one half of the above amount, or $\frac{1}{60}$th of a centesimal degree, it would require the enormous period of one hundred thousand millions of years. It

* If f denote the excess of the present superficial temperature above the final limit to which the temperature would descend in an indefinite period of time, and g the rate of increase of temperature mentioned in the text, we have $\frac{f}{g} = b$, where b is nearly equal to unity.

would, doubtless, require us to go back into the past some such immense period as this to arrive at the epoch when the superficial temperature should have exceeded its present amount by even one or two degrees. At the same time the rate of increase of temperature in descending beneath the surface would be much more rapid than at present. If the superficial temperature amounted to 2° C. above its ultimate limit, instead of being $\frac{1}{30}$th of a degree, the rate at which the temperature would increase in descending would be about sixty times as great as at present, i. e. there would be an increase of 1° C. for little more than one foot of depth.

It must be recollected that this state of terrestrial temperature, if due to the cause we are considering, could only have existed at times which, even in a geological sense, must have been extremely remote. The important peculiarity of this state of the earth would seem to consist in the simultaneous existence of a superficial temperature, and therefore of climatal conditions, very nearly the same as at present, with an internal temperature at the depth of a few hundred feet and upwards, immensely greater than at present. If we suppose the process of sedimentary deposition to have been then going on, we may understand how great an effect might be produced by this internal temperature in the metamorphism of the earlier sedimentary beds.

The temperature of any point in stellar space is that which would be indicated by a thermometer at that point receiving the heat radiating from all the stars composing the universe. The temperature of all bodies must necessarily be affected by this radiation, and in different degrees, according to the positions in space which they may occupy. Hence Poisson was led to adopt the notion that the actual temperature of the earth, whether superficial or internal, is due to the circumstance of the solar system having passed through a warmer region than that which it now occupies, in the course of that motion by which astronomers generally believe it to be constantly moving from one part of space to another. What may have been the possible effect of this cause in the lapse of indefinite time, it is impossible to say; but I cannot understand how it could be very considerable without a totally different distribution of the group of stars to which the sun should belong, or the near approach of the solar system to some individual star. The latter hypothesis, however, would be inconsistent with the integrity of the solar system as it now exists, if we suppose the proximity to any single star to become such as to produce any material modification of terrestrial climate; and perhaps it may be difficult to conceive how the first hypothesis should escape a similar objection. At all events, it may be regarded as certain, that according to neither of these hypothesis can any considerable effects have been produced by this cause on terrestrial temperature within the later Tertiary period, and that we cannot thus account for the cold of the glacial epoch.

In considering the influence of the third cause—that of the configuration of land and sea—I have endeavoured to ascertain approximately what would be the climatal conditions, more especially in western Europe, in the four following hypothetical cases:—

1. The configuration of land and sea the same as at present, but without the Gulf-stream.

2. The Gulf-stream the same as at present, except that its progress into the North Sea is supposed to be arrested by a barrier of land, extending from the north of Scotland to Iceland, and thence to the coast of Greenland.

3. The basin of the Atlantic from the Tropic to the North Sea converted into land, uniting the old and new continents.

4. Large portions of the continents of Europe and North America submerged beneath the surface of the ocean, and the Gulf-stream diverted into some other course.

By a study of Dove's admirable map of isothermal lines, we easily recognize the masses of land in the northern parts of the old and new continents, and the Gulf-stream as the principal causes of the abnormal forms of the isothermals in the higher latitudes of the northern hemisphere. In like manner the irregular forms of the known isothermals of the southern hemisphere, extending to about the latitude of 50°, may be seen to be attributable to similar causes, more especially, perhaps, in this case to well-known ocean-currents; and a knowledge of these causes enables us to draw the isothermals in such hypothetical cases, as those above-stated, with approximate accuracy. This is what I have first attempted to do in the memoir before us.

Taking the first case, I arrive at the results embodied in the following table :—.

	At present, with the Gulf Stream.	Difference.	Without the Gulf Stream.	Difference.
The Alps.				
Temperature for January	38° F.	35°	34° F.	39°
„ „ July	73		73	
Mean annual temperature	55·5		53·5	
Snowdon.				
Temperature for January	38 F.	23	23 F.	38
„ „ July	61		61	
Mean annual temperature	49·5		42	
Northern Extremity of Scotland.				
Temperature for January	36·5 F.	19·5	12 F.	44
„ „ July	56		56	
Mean annual temperature	46·25		34	
Centre of Iceland.				
Temperature for January	30 F.	22	−4 F.	50
„ „ July	52		46	
Mean	41		21	
Mean annual temperature*	39			

* This is deduced from the mean of the monthly temperatures. The mean annual temperatures above given for the other cases are almost identical with those deduced from the monthly temperatures. The discrepancy of 3° in the case of Iceland may be attributed to local peculiarities.

In the case in which the Gulf-stream is supposed to exist, but its progress into the North Sea to be arrested by a continuous barrier of land, I have shown that the winter temperature of the coast of Iceland would probably be increased 6° or 7° F., and that the January isothermal would probably run nearly north and south from Iceland to the latitude of central France. You will recollect that a former littoral or sub-littoral communication between the western coasts of Europe and the eastern coasts of America is rendered probable by a certain community of specific forms in those localities. My object, in considering the effect of the configuration of land above-mentioned, is to determine how far it might afford this littoral communication with a temperature of the ocean sufficiently high to admit of the dissemination along it of the species alluded to.

The next case is that in which the basin of the Atlantic should be converted into dry land, so as to unite the old and new continents. This would give to our own region the extreme continental climate of northern and central Asia. According to my estimate, we should then have for Snowdon,

Temperature of January....	7° F.	Diff. 73°·5.
„ July	66°·5	
Mean annual temperature ..	29°·75	

The summer temperature would be increased 5°·5 F., but the winter temperature would be reduced 45°, and the mean annual temperature 20°.

In discussing the fourth case, in which the Gulf-stream is not supposed to exist on our own shores, and a great part of Europe is assumed to be submerged beneath the ocean, I have shown that the mean annual temperature would be very nearly the same in western Europe and in the latitude of Snowdon, as in the case above-considered of simply the absence of the Gulf-stream. The conditions under which the Welsh and Irish mountains would be placed, supposing them extant above the sea while the neighbouring region was submerged, would be very similar to the existing conditions of the Falkland Islands and the island of S. Georgia; and a comparison with these islands leads me to conclude that the estimate above-given of the mean annual temperature of Snowdon (42° F.) is two or three degrees too high. I have considered 39° or 40° F. to be a nearer estimate. In fact, a great part of the misconception which has existed respecting the possible past temperature of this region, has arisen from our regarding its present temperature as the normal temperature for our own latitude, and that of places like the island of S. Georgia, in corresponding south latitudes, as the abnormal temperature; whereas the exact reverse of this is the actual case.

Having determined the positions of the isothermal lines for any particular hypothetical case, we can determine, for that case, the mean annual temperature at any assigned place. The object which I have next proposed to myself in this paper is more especially to determine the conditions under which glaciers would exist in those parts of western Europe where traces of their former existence have

been observed. The principle on which I have proceeded is easily explained. The *snow-line* is that line on the side of a mountain which forms the highest limit to which the boundary of the snow ascends during the year. It bears an important relation to all glaciers, being that limit below which the glacier receives no permanent superficial increase. Below this limit the destructive begin to prevail over the productive agencies. The distance to which the glacier descends below it depends on local circumstances, but we find that nearly all glaciers, large enough to be considered of the first order, descend to levels lower than the snow-line by an amount varying from about 4000 to 5000 feet. In smaller glaciers the descent is proportionally less. Again, the snow-line bears certain relations to the line which I have defined as the *line of* 32° F., or that along which the mean annual temperature is equal to 32° F. At certain places in sufficiently high latitudes this line will lie at the level of the sea. In lower latitudes it will lie at higher levels, and in still higher latitudes the mean annual temperature will be less than 32°. It is found that at the equator the snow-line lies about 1000 feet below the line of 32°, while in the higher north latitudes it lies above the latter line, the vertical distance between them being very variable. A continental climate, in which the atmosphere contains comparatively little moisture, and the variation from summer to winter temperature is very great, is favourable to a relatively high position of the snow-line; while an insular climate, in which the quantity of moisture is comparatively large, and the annual variation of temperature comparatively small, superinduces a relatively low position of this line. Thus in the north-eastern part of Asia, the snow-line is probably from 4000 to 6000 feet above the line of 32°, while in Iceland its height above the latter line does not exceed a few hundred feet. A knowledge of these facts enables us to estimate approximately the vertical distance between these lines in any proposed hypothetical case. To estimate the absolute height of the snow-line above the sea-level, we have only then to calculate the height of the line of 32° at the place proposed. For this purpose we must estimate the mean annual temperature there by means of the isothermal line passing through the place, and then calculate the vertical height to which we must ascend to reach the point at which the mean annual temperature is equal to 32°; and to effect this we must know the height which corresponds to a decrease of temperature of 1°. Humboldt and others have shown that this height may be taken as varying from about 320 to 350 feet in ascending steep mountains, or vertically in a balloon; but Humboldt has also shown, from his own observations, that, in an ascent presenting a succession of high and extensive table lands, the increase of height for each degree may amount to 450 or 500 feet. This is an important distinction.

In this manner, then, the height of the snow-line above the sea-level can be estimated at any proposed place, with any hypothetical distribution of land and sea. If a mountain rise a few hundred feet at least above the snow-line, and the configuration of its summit be favourable, glaciers will be formed upon it, of which the magnitude will depend

on circumstances. If large, we might expect them to descend 4000 or 5000 feet below the snow-line, and to distances proportionally less, when the glaciers should be small.

As an example, we may take Snowdon, in the case in which the Gulf-stream is supposed to be absent from the shores of western Europe, and a large portion of that continent submerged beneath the ocean, I have shown that the temperature of Snowdon would probably not exceed 39° or 40° F. Assume it 39°. Taking a decrease of temperature of 1° in ascending 320 feet, the height of the line of 32° would be 2240 feet. The climate would be entirely an insular one, and therefore the height of the snow-line would probably not exceed that of the line of 32° by more than 200 or 300 feet. If we suppose this additional height to be 260 feet, the absolute height of the snow-line would be 2500 feet, or 1000 feet less than that of the present summit of the mountain. If we assume the mountain to subside 400 or 500 feet with the surrounding region, it would still rise 500 or 600 feet above the snow-line, a height sufficient to admit of the formation of glaciers, which might descend to the level of the sea. If, in addition to the hypothesis of the absence of the Gulf-stream, we adopt also that of a cold current from the north, the mean annual temperature might be reduced 3° or 4° F. lower than above supposed, which would reduce the height of the snow-line to 1200 or 1500 feet. This would admit of the formation of glaciers, not only on Snowdon, but also on the lower mountains of Ireland. And I may here remark, that if we can thus account satisfactorily for climatal conditions consistent with the existence of glaciers in the south-west of Ireland, the subject presents no difficulty with reference to any other part of western Europe, in which we observe the traces of glacial action.

For the application of the same method of investigation to the other hypothetical cases of the distribution of land and sea, I must refer to the memoir of which I am speaking. I have selected the above case, not only because it seemed best calculated to elucidate the subject, but also because I consider it that which has far the highest claim to our acceptance as the real one of the glacial epoch. It involves, as we have seen, the absence of the Gulf-stream as an essential condition, the explanation which it affords of the existence of ancient glaciers being rendered more complete by the supposition of a cold current from the north. On these points it remains for me to say a few words.

I need scarcely remind you that the evidence of the submergence of a very large portion of the North American continent during the Drift-period is similar to that for the submergence of Europe. A subsidence of less than 2000 feet would render the ocean continuous from the Apalachian chain, on the east, to the Rocky Mountains on the west, and there seems reason to believe that the subsidence may possibly have attained to a considerably greater amount. Now it is manifest that the Gulf-stream is reflected in a north-easterly direction across the Atlantic, by the continent of North America, which arrests the north-westerly course by which the current reaches the

Gulf of Mexico. But when that continent was submerged, as above supposed, the current would necessarily continue its north-westerly course, and probably along the foot of the Rocky Mountains directly into the Arctic Sea. This is the manner in which I conceive the Gulf-stream to have been diverted from the shores of western Europe. This diversion of the current is not to be regarded as a mere hypothesis adopted to account for any particular fact, but as a necessary consequence of that submergence of the North American continent.

Again, if this enormous current discharged itself into the Arctic Sea, it would seem extremely improbable that it should not give rise to some great determinate counter-current *out* of that sea. Now it appears highly probable that a considerable tract of land must have existed at the period of which we are speaking in the present region of north-eastern America, and Greenland. If this were the case, the only practicable outlet for a great current from the Arctic Sea would be across the submerged portion of northern Europe, or along the present North Sea, between Greenland and Norway; for the passage through Behring's Straits, even with a considerable subsidence of the land on either side, would be neither sufficiently wide nor deep to form a considerable outlet. Under such circumstances, it would scarcely seem more necessary that the Gulf-stream should hold its original north-westerly course over the submerged continent of America, than that it should complete its circuit by passing through the Arctic Sea, and returning to the Atlantic across the submerged land of Europe, as it now completes a more circumscribed circuit by being constrained to pass along the northern portion of the Atlantic itself.

The effect of this diversion of the Gulf-stream from its present course, would not be less remarkable in elevating the temperature of the northern shores of America and Asia, than in reducing that of western Europe. I have shown that the mean annual temperature of Iceland is increased 18° or 20° F., and the January temperature 34°, by the influence of this important current. Now the distance from the Gulf of Mexico to Behring's Straits is very little greater than the distance between that gulf and Iceland, and the passage of the stream along the flanks of the Rocky Mountains would be more direct, and probably less impeded by counter-currents than it is at present in its transatlantic course. There can be no reasonable doubt, therefore, of its raising the temperature of the north-western coast of America, from the Mackenzie river to Behring's Straits, by an amount at least equal to that by which it now elevates the temperature of Iceland. Further, it is highly probable that the principal course of the current in the Arctic Sea would not be far from the coasts of northern Asia, the temperature of which would thus be affected in a manner similar to that of the coast of America eastward of Behring's Straits, although in a smaller degree for greater distances on the west of the Straits. The temperature of winter immediately east of the Ural Mountains would also be considerably moderated, as already stated, by the extension of the European sea towards their western flanks. The climate of the low lands of northern Asia would thus differ from the present climate of that region, as much as the existing climate of the

western coast of Norway differs from that which would desolate that region in the absence of the Gulf-stream.

According to this view of the subject, the former existence in northern Asia of the immense numbers of large Mammalia indicated by the abundance of their fossil remains no longer presents the slightest difficulty; and the theory receives a still further confirmation from an observation made by Sir John Richardson in his 'Arctic Searching Expedition *,' just published. The author observes, "The existence of these numerous testimonials of an ancient fauna is suggestive of many curious speculations, and geologists seem hitherto to have failed in explaining the circumstances under which accumulations so vast could occur in such high latitudes. The difficulty is increased when we consider that these bones have not been detected to the east of the Rocky Mountains in high latitudes." This increased difficulty, however, is at once removed by the theory now proposed, for the region in which these remains are not found, must either have been covered with the waters of the ocean to the foot of the Rocky Mountains at the period when these Mammalia occupied the region to the westward, or, if land existed on the north-east of the present American continent, it was probably too cold to be inhabited by them. Their disappearance from the country bounding the Arctic Sea, from the Rocky Mountains to the Ural, would be the consequence of the withdrawal of the Gulf-stream from the more eastern, and of the European ocean from the more westerly portion of that region. Fossil plants also, belonging to a comparatively warm climate, have been found east of the Rocky Mountains, on the coast of the North Sea; and extensive beds of lignite exist along the eastern flank of those mountains. So far as these phænomena may be of Pleistocene origin, they may be at once accounted for by this theory. Its more complete verification must, however, be left to future observation. It will not fail, I hope, to attract the attention of American geologists.

I have now, Gentlemen, completed my review of those papers which have been brought before us during my year of office, bearing upon the phænomena of the Drift, and the causes to which its dispersion is to be referred. This discussion has occupied too much time to leave room for extended remarks on papers relating to other branches of our science. Some of them, however, are too important to be passed over in silence.

The first of these papers to which I shall call your attention is an excellent paper by Captain Strachey, which gives us a section of the Himalaya chain far more complete than any we have hitherto possessed. It will be recollected that this magnificent chain extends through a length of more than 2000 miles, comprising 1500 miles of continuous range between the points at which the Brahmapootra and the Indus break through it in deep transverse gorges. The section given by Captain Strachey is somewhat to the west of the centre of this range, and lies about the 30th degree of north latitude and the 80th of east longitude. The Kali, a tributary of the Ganges,

* Vol. ii. p. 210.

rises on the south side of the range of which we have here the section, and the Sutlej in the deep longitudinal valley on the northern side, the distance between the points at which they leave the mountains being about 200 miles. It is to a portion of this intervening district, extending from the northern boundary of the plains of India for about 120 miles in breadth, that the observations of the author have been principally restricted. The section runs S.S.W. to N.N.E.

The southern extremity of this section meets the great plain of India at an elevation of 1200 feet above the sea, the maximum height of the plain. It here constitutes the watershed between the valleys of the Indus and the Ganges. It seems scarcely conceivable that the deposits of this plain should be otherwise than marine, although the opinion has not yet been confirmed, it seems, by the discovery of marine remains. The Siwalik Hills, forming a sub-Himalayan range, appear to extend almost uninterruptedly from the Sutlej to the meridian of Calcutta. Along the line of section they dip towards the mountains at an angle of about 5°. The author could not discover any fossils which might determine their age more definitely than has been done already by the discoveries of Dr. Falconer and Captain Cautley.

Proceeding further N.W., Captain Strachey finds a series of old non-fossiliferous rocks of enormous thickness, reaching generally the height of 14,000 feet. They consist of metamorphic beds, crystalline schists, limestones, conglomerates, &c., and are for the most part distinctly stratified. The mean strike appears to coincide accurately with the direction of the chain; the dip is most frequently inwards, N.N.W., although with not unfrequent instances of exactly the opposite dip. The whole thus presents a series of anticlinal and synclinal lines; but with the portions of the beds dipping S.S.W. much shorter, estimated in the direction of the section, than those dipping N.N.E. All the great lines of eruptive rock appear to coincide with the direction of the strike of the beds.

At the height of about 14,000 feet, the author came upon a series of fossiliferous strata, which are clearly proved by the fossils to be Lower Silurian. A list is given of a considerable number of the fossils, which have been identified with the characteristic fossils of those strata in our own region. The author could only verify the existence of these beds for about 50 miles longitudinally; but there can be no doubt of their wide development along this magnificent range. Their height in this part of it appears to be from 14,000 to 18,000 or 20,000 feet.

These Palæozoic beds seem to be terminated along the line of section by a great fault, to which succeed beds with the character of the Muschelkalk of Europe. Here a considerable number of shells was found, among which were *Ceratites*, *Goniatites*, *Ammonites*, *Spirifer*, *Pecten*, *Terebratula*, and *Pholadomya*. The relative position of these beds, however, with reference to the beds below, was not so well made out as in other cases. In ascending order, beds come next which appear to represent the Jurassic series, but the representative of the Lias appeared to be wanting. Above these again are dark-

coloured shales, which Prof. Forbes pronounces, on examining the fossils, to be unequivocally of the age of our Oxford Clay. A peculiar and characteristic form of Ammonite found here has also been discovered in Cutch and Scinde.

But, as Captain Strachey has remarked, the most striking and novel feature in this section is the existence of a great Tertiary deposit at the height of 14,000 or 16,000 feet above the sea. These beds form the surface of a plain, about 120 miles long, and from 15 to 60 miles wide, on the high land lying on the northern side of the watershed from which the waters descend to the Ganges on the south, and into the Sutlej on the north. Towards its western end, the latter river has cut a ravine to the depth of nearly 3000 feet. The section made by this and similar ravines enables the observer to see the nature of the beds and their stratification. They consist of boulders, gravel, and finer argillaceous or arenaceous matter, horizontally stratified.

That these beds belong to the Tertiary period appears to be proved beyond doubt by the remains of several of the large Mammalia of that period. Unfortunately, however, these remains are too imperfect to admit of their being identified with those of the Siwalik Hills. At present, therefore, we have very imperfect data for judging of the particular part of the Tertiary period to which these remains may belong. There is also another important point still in doubt. There is no evidence at present to decide whether this deposit is marine or freshwater. The author inclines to the opinion that it is marine.

It is not too much, I think, to say of this section, that it is the most magnificent one which geologists have ever had presented to them from one locality. It embraces an enormous series of the lower non-fossiliferous strata, distinctly stratified, a large Palæozoic series, together with an equally important development of secondary strata, with a singularly striking approximation to absolute order of superposition; nor can I conceive a section better adapted to silence the geological sceptic as to the immense revolutions which our globe has undergone, or the enormous periods of time which have been necessary to effect them. We have here a sketch of a noble picture for the geological eye; and, although its details may never be filled up in our day, we may still contemplate it in our imagination, and recognize its importance. I rejoice in this opportunity of expressing my own sense, and, I feel sure, not less the sense which you also entertain, of the valuable service which Captain Strachey has rendered us. Nor can I help commending him for the modesty, as well as for the perspicuity with which he has given the details of his paper. We may envy him the interest which must have attached to his researches in so novel a field of geological inquiry, and the views of nature in the magnificent aspects under which she must often present herself in these varied, but often wild and desolate regions; but we must recollect, Gentlemen, that these regions can only be approached, for the purposes of detailed research, with the sacrifice of personal comfort, and a subjection to physical labour, and frequently to physical suffering, which many would be unable to bear, and few are willing to

undergo in the research of scientific truth. The man who does thus submit to hardships and privations, and almost without an allusion to them by himself, has surely a just claim, on an occasion like the present, to all due praise, not only for the merit of his researches, but also for the modesty with which he has described them.

It may, perhaps, appear somewhat premature to enter upon any theoretical discussion of the phænomena of a region with which we are at present so imperfectly acquainted; but the indications of determinate laws in the phænomena of elevation are so distinct, that what may now be merely matter of inference, will, I doubt not, be hereafter verified as matter of observation. As far as Captain Strachey's observations extended, he found that the directions of all the great longitudinal valleys, faults, anticlinal and synclinal lines, lines of eruptive matter, &c. coincided with the general strike of the beds; while the transverse valleys coincide equally with the direction of the dip. I need scarcely remind you that this is the law deduced from the theory which rests on the supposition, as its fundamental hypothesis, of the simultaneous action of an upheaving force at every point of the area over which the phænomena of elevation preserve a certain character of continuity. And here I would observe that it is destructive of all just conception of this dynamical theory to suppose the elevating force to have acted *along the lines of dislocation*, as if distinct forces had been necessary to produce each separate dislocation; whereas the upheaving force, although it may have acted with different degrees of intensity at different points, is not necessarily assumed to have done so. It may have been, like the pressure of a perfect fluid, equal at every point. Thus the elevated mass, fixed at the horizontal boundary, within which the elevating force is supposed to act, becomes stretched, and is ultimately torn and fissured in those directions in which the tendency thus to tear it is greatest, or rather bears the greatest ratio to the power of resistance. It is thus that the complex phænomena of elevation become referable to a general and simple mechanical cause, and not to a mode of action as complex as the phænomena themselves, as would be the case if each particular line of dislocation were due to the action of an especial force along that line.

The boundary of a district, which is supposed to be thus simultaneously elevated, is not necessarily defined by those existing physical features which might seem at first sight to define it. Thus, if we take the great ridge of our own country, from Derbyshire to Northumberland, we find that, generally, the country on the lower or western side of the accompanying faults is far more dislocated and disturbed than the elevated or eastern side. In such cases I consider the first movement of disturbance to have been one of elevation, succeeded by an immediate subsidence of the lower side of the district, for want of sufficient support to maintain it in its more elevated position. It is in this subsidence that I conceive the effects of all that lateral crushing to have been produced, which has so frequently given the strata subjected to it vertical or even reversed positions, or folded and crumpled them into such singular contortions; for it is

demonstrable that in this manner horizontal pressure may be called into action, indefinitely greater than the vertical forces necessary to raise the elevated mass. Hence it is that the subsided portion appears to be frequently more broken and confused than that which retains its elevated position. But, according to this view, the elevated ridge which might appear to form the physical boundary of the disturbed district would, in fact, be its central axis, as I conceive it to be in the example above quoted in our own country. In like manner, I think it highly probable that the older beds subjacent to the modern deposit of the great plain of India, immediately on the south of the Himalayas, could they be examined, would be found far more broken and disturbed than those which constitute the range itself. And in fact indications of this kind have been incidentally noticed in the nearly vertical position of some of the older slate-rocks observed by Major Vicary in the Punjaub*. And thus, at present, I regard the chain of the Himalayas as the axis of a disturbance probably of 3000 miles in length, and of which the breadth, not yet determined, is, in all probability, comparatively small. Such a district, according to this theory, would necessarily be characterized by longitudinal faults, valleys, anticlinal lines, &c., intersected by transverse faults, valleys, river-gorges, &c., such as appear to exist in this range so far as it is known. I must not be understood, however, as appealing to this district in confirmation of my theoretical views; our knowledge of it is far too imperfect to admit of such appeal. I have here stated these views, not as confirmed in this application of them by observations already made, but merely as suggested by those observations, and as anticipatory of those which will be made hereafter.

In the consideration of the movements which have given to any geological district its existing internal conformation, and its external configuration, so far as it depends on the disturbed positions of its component beds, it should be always borne in mind that those movements may possibly have been long anterior to other movements which may have been less disruptive, perhaps less paroxysmal, and possibly of wider extent, but more effective, in the aggregate, in giving elevation above the level of the sea. These two series of movements, although probably intimately connected as to their physical causes, may have very distant relations to each other with reference to time. The existence of Tertiary beds at the enormous height of those recognized by Captain Strachey in the Himalayas is itself surprising; the disturbed horizontality of the beds makes it much more so; and if their marine origin should be hereafter established, it will be unquestionably one of the most curious and striking facts that geology has revealed to us respecting the movements of the crust of our globe. Its deposition after the surrounding mountains had acquired their general external relief and internal conformation, I presume to be fully proved by the want of conformability of stratification; but notwithstanding the possible independence, in time, of the disruptive movements, and those which gave elevation to the

* Quart. Journ. Geol. Soc., vol. vii. p. 44.

general mass, the subsequent upheaval of the whole chain to the height of 13,000 or 14,000 feet, not only without dislocating these Tertiary strata, but without even destroying their horizontality, appears to be so improbable, that we ought not to adopt the conclusion, and much less ought we to make it the foundation of other reasonings, until the marine origin of these strata is established by decisive evidence. The further investigation of their age, structure, and characters will be full of interest, and may enable us to draw the most important conclusions as to the nature of the movements which have resulted in the formation of this grandest physical feature which the surface of our globe presents to us.

On the geology of the Palæozoic rocks several papers have been presented to us in the course of the year. Sir R. I. Murchison has given us one "On the Silurian Rocks of the South of Scotland," and Mr. Harkness another on the similar rocks of Dumfriesshire and Kirkcudbrightshire. Professor Sedgwick has given us a paper "On the Slate Rocks of Devon and Cornwall;" and another "On the Lower Palæozoic Rocks of Westmoreland and Yorkshire." Mr. D. Sharpe has also read a communication "On the Quartz Rock of Macculloch's Map of Scotland."

Both these last-named gentlemen have announced their intention of making further communications to us on subjects nearly allied to those of their respective papers just mentioned, and therefore, since the views of these two able geologists on these subjects are at present but imperfectly before us, I shall postpone any remarks upon them until a future opportunity. There is one subject, however, of too much immediate interest to be passed over in silence, I allude to the discovery of Reptilian Foot-prints, and that of the skeleton of a Reptile in rocks belonging to these ancient formations. The fossil Reptile is from the Old Red Sandstone of Morayshire, and was obtained by Mr. Patrick Duff, and described by Dr. Mantell at one of our late meetings*, under the name of the *Telerpeton Elginense*. As the paper containing this description has not yet appeared in print, I have been favoured by Dr. Mantell with the following description of this beautiful specimen, as well as of the foot-prints which have been observed by Captain Lambart Brickenden on a slab of the same rock.

"The specimen consists of the distinct impression of the entire skeleton of a four-footed reptile, about 6 or 7 inches in length. The skull is crushed and partially enveloped in the stone, so that its normal characters cannot be determined; and the imprints of the feet are concealed. The structure of the vertebral column, the form of the pelvis, as indicated by the imprints, and the slenderness of the ribs resemble in many respects those of certain Batrachians, while the form of the extremities, the length of the ribs, and the relative proportions of the general form of the skeleton are nearly allied to the Lacertian modification of structure. The original animal was a small air-breathing reptile, probably resembling in its aspect the Tritons or Aquatic Salamanders, but with a wider dorsal region and

* The same fossil has also been described by Prof. Owen, in the Literary Gazette of December 20, 1851, under the name of *Leptopleuron lacertinum*.

longer limbs, and with a wide, laterally compressed tail: its habits were probably aquatic.

"The quadrupedal foot-tracks discovered by Capt. Lambart Brickenden, resemble those usually ascribed to terrestrial or lacustrine Chelonians.

"The *Stagonolepis Robertsoni*, Agassiz, the only other organism found in the same rock, is a ganoid fish, with sculptured scales, closely resembling the Old Red Sandstone genus *Glyptopomus*, Agass."

You will also recollect that Mr. Logan has communicated to us during the past year a notice of the discovery of foot-prints in the Potsdam Sandstone of North America. Prof. Owen considers them to be either Batrachian or Chelonian. These are facts of especial interest, as indicating the existence of vertebrate animals in an early portion of the Silurian period. Mr. Logan has recently brought over from Canada some large slabs with the foot-marks upon them, and an extensive series of casts of others, now exhibited in the Museum of our Society. The removal of slabs of such magnitude has not been accomplished without considerable expense and great labour; and we are bound to express to Mr. Logan our obligation to him for the zeal and energy he has shown in thus placing these magnificent specimens within our reach.

The discovery in a single year of so much incontrovertible evidence of the extension of reptilian remains into some of the lowest fossiliferous strata is very remarkable, and calculated to add greatly to the interest of the discussion of the theory of the progression of organic forms during successive geological epochs, which has lately occupied the minds of geologists.

It will be recollected that the advocates of the doctrine of progression, as well as the distinguished geologist who has been their principal opponent, distinctly repudiate the idea of the *progression* here spoken of involving any notion of the transmutation of species, a theory to which, as you well know, they have been most strongly opposed. They merely assert their belief that there has been upon the whole "a gradual ascent towards a higher type of being*," from the earliest to the latest geological periods. They would also contend for a certain progression in the physical state of our planet, "a gradual improvement in the style and character of the dwelling-place of organized beings†." These are the propositions which your late distinguished President combated in the two Addresses which he delivered from this chair.

It would be absurd to contend that either the first of these propositions or its negative have been yet established by demonstrative evidence. The advocate of progression can only reason on the confessedly imperfect evidence which we at present possess respecting the extent and variety of organic beings which existed at the earliest geological period to which we can refer the organic remains with which we are acquainted; and so far as his opponent proves to us more clearly the incompleteness of this evidence, and thus inspires us with

* Prof. Sedgwick, 'Discourse on the Studies of Cambridge,' Preface, p. cliv.

† Mr. Hugh Miller, 'Foot-prints of the Creator.'

due caution in forming our opinions, he renders service to the sound progress of speculative views on the subject. But if he goes further than this, and asserts the truth of the opposite proposition, he places himself in a position at least as untenable as that which he combats. If land existed when the earth first became the abode of animate beings, it would seem probable that animals adapted for such a dwelling-place should have been then created, and possibly in much greater numbers than the organic remains of the earlier geological periods might at present seem to indicate; nor need we be surprised at any future discoveries tending to support this view. Every fresh discovery like those above mentioned brings us a step nearer to that ultimate limit to which our evidence can finally hereafter attain; but, even if we make many more such additional steps, we must still be cautious how we adopt the opinion that that limit will indicate an absolute equality between the organization of the earliest created beings and those which now exist,—exclusive, I mean, of man, whose recent introduction on the earth is admitted equally by the contending parties. It is not here my purpose to advocate the one view or the other in mere especial reference to organized beings, or to analyse the evidence which has been adduced with so much ability both in favour of the doctrine of progression and in opposition to it; but to insist on that philosophic caution and reserve which may leave us unshackled in our future speculations, and free to modify our opinions so far as future evidence may call upon us to do so.

So long as we restrict our speculations on the question of progression to organic life, we are in no danger of adopting conclusions inconsistent with what we know of the operation of natural causes, because we are ignorant of those laws by which the succession of organic life has been regulated since its introduction on the earth. Progression in organic structure, or the entire absence of it, may, for aught we know, be perfectly consistent with those laws. But the operations of nature have revealed much more to us respecting the laws which have been appointed for the government of the inorganic world, and it becomes us to examine how far these laws may be consistent with the doctrine of non-progression in its application to the *inorganic* matter of our planet, or how far they indicate a necessary tendency, in the language above-quoted, to "a gradual improvement in the style and character of the dwelling-place of organized beings."

And here I would remark that the doctrine of non-progression, in the sense in which I use the term, is independent of that theory which would attribute all geological phænomena to causes acting with no greater intensity than those of which we now witness the operation around us. By *progression*, as applied to the inorganic matter composing our planet, I understand a change, continuous or discontinuous, by which that matter has passed in the long process of time from a primitive to its present condition, and may still pass to some ultimate and different state, a change by which, regarded in more especial reference to the question before us, the surface of the earth has been rendered more fit for the habitation of the higher orders of organized beings. This permanent change of state may have been

effected or accompanied by either *paroxysmal* or gradual and uniform action of the forces which have modified the earth's surface. By *non-progression* I understand, not the absence of *periodically recurring* changes, but of that *permanent* change above mentioned. The periodical changes in this case, equally with the permanent changes of the former case, may have been produced or accompanied by either paroxysmal or uniform action. The *theory of non-progression* is essentially different from the *theory of uniformity*; and thus while we might allow the justice of the appeal to the Alps, made by my distinguished predecessor in this chair, in proof of non-progression as indicated by an apparent equality of intensity in the more recent and the more remote geological action, we might reject the appeal if made to prove that the forces which elevated the Alps were of no greater intensity than those which have been in action during the historic period.

It is not then, I conceive, to the phænomena of elevation, or of denudation and deposition, as indicating more or less of paroxysmal or tranquil action, that we must look for any demonstrative evidence to decide the question before us. But there is one most important agent which has doubtless been most active, not only in producing the phænomena of elevation, but also in modifying the characters of the inorganic matter composing the crust of the globe, and it is extremely difficult to conceive how the activity of that agent can have consisted with non-progression. The agent I speak of is *heat*. I assume the truth of the simple proposition, that *if a mass of matter, such, for instance, as the earth with its waters and its atmosphere, be placed in space of which the temperature is lower than its own, it will necessarily lose a portion of its heat by radiation, until its temperature ultimately approximates to that of the circumambient space, unless this reduction of temperature be prevented by the continued generation of heat.* If there be any propositions in experimental science which may be deemed incontrovertible, this, I conceive, is one of them. Now we know that the interior temperature of the earth is higher than that of its surface; and, in order that this state of terrestrial temperature may be consistent with non-progression, it must either be a permanent state, or must belong to a series of changes recurring periodically, but producing no permanent change or progression from a higher primitive to a lower ultimate temperature. If the present temperature be permanent, it must be maintained by some cause constantly acting within the earth and generating a quantity of heat exactly equal to that which is lost by radiation into surrounding space. No external cause, such as solar or stellar radiation, could produce an absolutely constant, stationary temperature, which should increase in descending beneath the earth's surface. Chemical action might produce this effect, possibly, for a *finite* time, but philosophers, I imagine, would no more believe that or any other internal cause capable of producing such an effect for an *infinite* time, than they would believe in perpetual motion, in the ordinary sense of the expression. I cannot conceive, therefore, the present state of terrestrial temperature to be a *permanent* state. Can it belong to a perpetually recurring series of changes? I would

reply, that no internal cause could account for any such *infinite* recurrence, more than for unlimited permanence of temperature. Such infinite recurrence could only be attributed to the external causes—solar and stellar radiation. If to the former, the quantity of heat radiating from the sun must be subject to enormous periodical changes, but still without permanent diminution; if to the latter, it might be attributed either to similar periodical changes in the radiation of the stars, or more probably to a change in the position of the solar system with reference to them, as I have explained in my paper on Terrestrial Temperature. But we shall probably all agree in regarding such hypotheses as extremely unsatisfactory, and utterly unfit to be made the foundation on which a great speculative theory may rest. But however unsatisfactory they may be, I repeat that we have no other alternative but that of adopting one of them, consistent with the most fundamental properties of heat, if we maintain the theory of non-progression in the strict sense in which I have used the term. And, having placed the theory in this point of view, I might leave it there, without venturing into those speculations which assume the properties of the matter, constituting the stellar universe, to be the same as those which characterize the matter of our planet. Views founded on such assumptions ought to be advanced with diffidence, and held with cautious reserve; but if, with such reservation, we assume the sun and the stars to have the same properties as our own planet, with respect to the generation and emission of heat, we must conclude that those bodies must be subject to permanent changes of temperature, as well as the earth itself, from the effect of radiation. In such case even solar and stellar radiation must necessarily fail to preserve the earth from that permanent change of temperature which would constitute essentially a state of progression. In fact, adopting the assumption just stated respecting the nature of the sun and stars, and reasoning from all we know of the properties of matter and of heat, I am unable in any manner to recognize the seal and impress of eternity stamped on the physical universe, regarded as subjected to those laws alone by which we conceive it at present to be governed.

The rejection of the doctrine of progression, both with respect to animate beings and inanimate matter, would seem to lead almost necessarily to the opinion, that the sequence of periodical changes, similar to those which have happened within the period of which we can trace the geological history, has been of infinite duration. It would appear to involve the rejection of the notion of a *beginning* of the actual physical condition of our planet. If not, the earth must have been created at once, at some finite distance of time, as fit a dwelling-place for organic beings, as it has been rendered, according to the theory of progression, only by a long series of superficial operations. In other words, phænomena must have existed as the immediate act of creation, and anterior to the operation of physical causes, which it is the very essence of geology to account for by reference to those causes. This would be to sap the foundations on which alone geology can rest as a physical science.

I would again, Gentlemen, carefully remind you that I have been

discussing these theories with reference to my own definitions of the terms which designate them, and which others may not have accepted in the same rigorous sense. Still I believe that, if they are to bear a determinate meaning, they must ultimately be received in the sense which I have assigned to them. In that sense, leaving the question entirely open respecting the organic creation to be decided by future research, I feel it impossible to adopt any other view than that of progressive development of inorganic matter from some primitive to its present state. I have already remarked that we do not know sufficient of the laws which may regulate the succession of organic life on our planet, to assert that the one of these theories or the other is most consistent with these laws; but, with respect to inorganic matter, the theories of uniformity and of non-progression appear to me incompatible with our most certain knowledge of the properties of heat—that ever-active agent in the work of terrestrial transformation.

It is far from my purpose to enter into a discussion of the evidence which might be deduced from recognized geological phænomena in favour of the theory of progression, but merely to insist on that which depends on the most immediate and simple inferences from the properties of heat. And here it should be remarked, that this argument cannot be refuted by any reasoning which may appear to establish an *approximate* general uniformity or non-progression in the character of geological phænomena since the earliest geological epochs, because the progressive refrigeration of the earth from some high temperature to its present temperature is perfectly consistent with such approximate uniformity or non-progression for enormous periods of time. Climatal conditions, for instance, may, consistently with the earth's continual refrigeration, have remained sensibly unaffected by the internal heat, as I have elsewhere explained, for millions of centuries; and the very theory which tells us that these conditions can never be sensibly altered in all future time (external circumstances remaining the same) essentially involves the hypothesis of progressive change towards an ultimate limit.

The contributions which we have received on the geology of the Secondary and Tertiary formations have not been numerous. I shall restrict myself to the brief notice of a paper by Professor E. Forbes, and one by his Grace the Duke of Argyll. The former is entitled "On the Estuary Beds and the Oxford Clay at Loch Staffin in Skye."

Sir R. Murchison, in a paper read by him before the Society in 1827, containing remarks on the strata of the north of Scotland, mentions his having found species of *Cyclas*, *Paludina*, *Neritina*, *Ostrea*, and *Mytilus*, in flattened masses or blocks of shelly limestone, on the shores of Loch Staffin, in the northern part of the Isle of Skye. Two species of the *Cyclas*, the *Paludina*, and the *Ostrea* were at that time considered identical with the fossils of one of the upper beds of the Weald Clay in the South-east of England, to which formation, therefore, it was naturally inferred, the blocks, in which these fossils existed, might belong. Prof. E. Forbes found similar blocks on

the shore of the bay, and also discovered the bed whence they had been derived. He also discovered, immediately above it, another fossiliferous bed, the fossils of which, comprising *Ammonites cordatus*, *Belemnites Owenii*, and *B. Beaumontianus*, distinctly proved it to be of the period of the Oxford Clay. This discovery at once removed the freshwater beds from all association with the Wealden strata.

In the section which the author gives to illustrate the geological structure of this part of Skye, we have represented, in ascending order,—

1. Lias.
2. Inferior Oolite.
3. Middle Oolite.
4. *Imperfectly Columnar Basalt.*
5. Estuary Beds.
6. Oxford Clay.
7. *Amygdaloidal Trap.*

Thus we have first, in order of time, the deposition of marine beds probably at considerable depths in the sea. Afterwards a mass of igneous matter appears to have been ejected over the surface, which became so elevated as to admit of the subsequent formation of the Estuary beds. Then succeeded depression of the terrestrial surface and the deposition of the Oxford Clay beds, followed in turn by another outpouring of igneous matter. The vesicular character of this latter mass, the author observes, may perhaps indicate its formation under a shallower sea.

This view of the geological sequence of events presupposes the bed of Columnar Basalt not to have been *injected* between the beds where it is now found. The hypothesis of its having been so injected is regarded by the author, for several reasons, as not entitled to much consideration.

The position of the Estuary beds naturally suggested to Professor Forbes a comparison between them and the similar beds intercalated with the carboniferous portion of the Oolitic strata of Brora in Sutherlandshire, and formerly referred to the Wealden formation. Two papers descriptive of these beds were read before the Society in 1843 and 1846 by Mr. Alex. Robertson. On comparing the Brora fossils, however, with those from Loch Staffin, Prof. E. Forbes found that all the species, with the exception of one, a little *Hydrobia* (*Paludina conulus*, of Robertson), in the one locality differed from those in the other. The author considers that much interesting work still remains to be done in investigating both the igneous phænomena and the palæontology of the Hebrides. The latter, especially, presents, in his opinion, one of the finest fields of discovery remaining to be examined in the British Islands.

According to the views of Prof. E. Forbes, we have seen that the volcanic action by which the lower bed of igneous rock, described by him, was produced, must be referred to the middle of the Oolitic period; and there is no proof that the bed of amygdaloidal Trap is of later date than the Secondary period. In the island of Mull, how-

ever, we have distinct proof of the continuance of violent volcanic action up to a date as late probably as the Middle Tertiary period. This has been established by the discovery, by the Duke of Argyll, of beds of Trap interstratified with tertiary and probably freshwater strata. The phænomena are described by his Grace in his paper read before the Society, Jan. 8, 1851, and entitled "On the Tertiary Beds of the Isle of Mull." It is accompanied by a "Note on the Vegetable Remains from Ardtun Head," by Prof. E. Forbes.

The extreme south-western portion of Mull consists of a long promontory, called the Ross of Mull, separated from the striking headland of Bourg, on the north, by Loch Scridden. It is deeply indented on its northern side by Loch Laigh, which runs nearly north and south. At the entrance of this loch, on its eastern shore, is the headland of Ardtun, which presents the phænomena forming the subject of this paper. They consist of alternations of volcanic products with beds containing numerous and extremely well-preserved vegetable remains, as shown in a small ravine, where alone the strata are sufficiently accessible to be examined. The following beds occur in descending order:—

1. Basalt, taking the form of rude pillars, about 16 feet thick.
2. The first leaf-bed, consisting of shaly matter, about 2 feet thick, and containing impressions of leaves and stems of plants.
3. A bed of volcanic ashes or tuff, 8 feet thick; being an ashy paste, full of white angular fragments or lapilli, for the most part siliceous. It has one great peculiarity. The whole of the beds are nearly horizontal, but dip slightly to the S.E., and in that direction the bed passes into a conglomerate of flints cohering by an exceedingly tenacious cement. One of these flints, found by the Duke of Argyll, not only possessed the appearance of a chalk-flint, but was also found to contain a fossilized organism, affording unequivocal proof of its origin.
4. The second leaf-bed, by far the richest in vegetable remains. It is about $2\frac{1}{2}$ feet thick; its lower part consisting almost entirely of a compressed mass of leaves. A few impressions of twigs are found even in the superincumbent bed of tuff.
5. A bed of tuff, similar to the one above mentioned, and 6 feet thick.
6. A seam of baked clay or fine mud, containing a few imperfect impressions of leaves, apparently similar to those of the superior beds. It is about $1\frac{1}{2}$ foot in thickness.
7. A dark, amorphous, amygdaloidal basalt.
8. Columnar basalt, descending beneath the sea-level.

The thickness of the two last-mentioned basalts can be better estimated a short distance east of the ravine, where they are respectively 48 and 10 feet thick. The superior volcanic beds are there thicker than at the ravine, the leaf-beds retaining the same thickness.

The author deduces several interesting conclusions from these phænomena. The leaves belong to existing families of the Dicotyledonous order; they consequently belong to the Tertiary period, and Prof. E. Forbes is disposed to refer them to the Miocene epoch. This

determines the age of all the volcanic beds above the lowest leaf-bed. There is also strong evidence of the volcanic action having been subaërial. The author also concludes that the leaves were accumulated during successive autumns in the still water of some shallow lake, on the spot in which they were afterwards covered up by an overflow of volcanic mud, or showers of volcanic ashes. The tertiary origin of these beds is also proved incontestably by the conglomerate of flints into which, as above mentioned, the volcanic bed, immediately beneath the upper leaf-bed, gradually passes. The author considers it probable that the flints and the matrix in which they are imbedded were ejected together as a muddy flood, which spread itself over the surrounding surface.

In the geological events of which we have such distinct evidence in the paper before us, and in that by Prof. E. Forbes previously noticed, we have very interesting and instructive portions of the geological history of this region since the commencement of the Oolitic period. We have, first, the deposition of the lower Oolites, probably in a sea of considerable depth, succeeded by the sudden overflow of volcanic matter, and the subsequent elevation of the surface, which placed it under approximately subaërial conditions, in the portion of the region, at least, in the neighbourhood of the Isle of Skye. There was then a depression and subsequent deposition of the upper Oolites, followed again by an enormous volcanic eruption, of which the Amygdaloidal Trap of that island is a portion. How far the Cretaceous series may have extended over this region we know not; but the flint-conglomerate, mentioned by the Duke of Argyll, is strongly indicative of its having extended at least to the island of Mull. His Grace points out the analogy which the upper beds of Trap at Ardtun bear to the basalts on the coast of Antrim, while he assimilates the lowest bed to the basaltic masses of Staffa. It is probable, then, that during the Cretaceous period, a part of this region, at least, underwent a great depression. After the deposition of the Chalk, came the outpourings of volcanic matter on the north coast of Ireland, and at the islands of Mull and Staffa, assuming the above-mentioned relation between the Traps of those islands. Whether these outpourings belong to the same portion of the Tertiary period may be doubtful, especially if the Ardtun beds be assumed to be Miocene, as Prof. Forbes is disposed to regard them. If the Antrim beds be not Eocene, the surface of the newly-deposited Chalk must probably have been elevated so as to prevent Eocene deposition upon it, and then again depressed to receive on its surface the mass of ejected Trap-rock superincumbent upon it. Again, on the coast of Mull, the surface, having been subaërial at the Miocene epoch, must have been again submerged during the Pleistocene period; and finally the whole region must have been again raised to its present elevation. Such are the oscillations which we are enabled to recognize in this region; possibly, however, they may form only a small part of the whole series of similar movements.

We are much indebted to the noble author of this paper for the interesting facts which he has brought under our notice; and, let me

add also, for the example which he has given us of perspicuity of style, of a clear and explicit statement of facts, and of sound and cautious induction.

I could have wished, Gentlemen, on this occasion to describe in some detail the admirable work which has been done by Prof. M'Coy in the arrangement of the fossils of the Woodwardian Museum at Cambridge, and for which we owe so much, not only to the zeal, but also to the private liberality of Prof. Sedgwick. But the limits to which I have professedly restricted myself in this Address, and the length to which it has already extended, prohibit my entering on a subject of this nature, for which, however, I hope to avail myself of a future occasion. I cannot, however, conclude without congratulating you on the opening of the Museum of Practical Geology, which has at once taken the rank of an important national institution. In our own Society it is our object to cultivate geology generally as a physical science, without especial reference to its practical applications. A true lover of the science will follow it for its own sake, for the pleasure of detecting new phænomena, or the laws which regulate them. He delights to contemplate it as the science which opens so many curious and deeply interesting views of the economy of the material universe, with reference both to organic and inorganic matter, and which tends to elevate our minds by leading us to the contemplation of such views. No science—not astronomy itself—has done more than geology to modify the convictions of men of cultivated minds, on some of the most important points of speculation to which physical science can lead us. And of this the geologist has a just title to be proud. But however we may delight to contemplate our science under this aspect, we should do it but partial justice if we omitted a due consideration of the practical benefits which it may produce by the promotion of those material interests, the progress of which, in the present state of the world, seems to be essentially connected with the advance of that civilization which consists in the due cultivation and improvement of the intellectual and moral faculties. The Museum of Practical Geology cannot fail to exercise an important influence. The lectures which have been instituted in connexion with it, and so admirably begun, will help to extend an abstract knowledge of geology and the allied sciences, and, by pointing out the practical applications of such knowledge, cannot fail to afford useful aids to some of the most important material interests of the country. Perhaps no one of these great interests has suffered more from the want of scientific knowledge than that of mining. In the vast extent of our mining products, the public only sees the result of that individual energy and enterprize which characterize our countrymen in all the practical pursuits of life, without seeing also the ignorance which, in so many cases, has formerly conducted, and the ruinous consequences which have often attended such enterprizes. Nor has this ignorance entailed heavy losses merely on a past generation. Its influence is still strongly felt in the want of those records of former mining operations, which, if they existed, would be so invaluable to the miner of the present day. Evils of this nature have

been already partially corrected by the wider diffusion of geological knowledge; but much still remains to be done to liberate mining interests entirely from the influence of real ignorance and pretended knowledge. I can conceive nothing more likely to effect this purpose than the establishment of this "School of Mines." Its opening has been perfectly successful. You have not, perhaps, now to learn that His Royal Highness the Prince of Wales, as Duke of Cornwall, has established two exhibitions of £30 a-year each for the benefit of pupils at the Museum. In this gracious act, we cannot fail to recognize the influence of that liberal and enlightened spirit which is conspicuous in His Royal Highness Prince Albert on every occasion which presents itself of promoting the moral and intellectual advancement of our country. To Sir Henry De la Beche, to whom, be it recollected, we owe so much of the extended advantages of this establishment, and to the distinguished men associated with him, we may offer our sincere congratulations on the successful commencement of the new phase which, practically, the institution has first assumed during the past year. I regard it not merely as useful in its own department, but as likely by its future success, to lead to a more extended recognition of the practical value of science by those who may be called upon to rule the destinies of our country.

Note.—*Lower Silurian Foot-tracks.*—While the preceding pages have been passing through the press, a further communication has been made to the Society, by Prof. Owen, on the footsteps found in Canada, containing conclusions different from those at which he had formerly arrived respecting the nature of the animals to which these footmarks are to be referred*. The specimens which have recently been subjected to his inspection by Mr. Logan, are far more perfect than those which he first examined, and have enabled him, after a very careful examination, and most ingenious analysis of the foot-prints, to decide that they do not belong to animals of the vertebrate class, as he had previously inferred. They probably belong, he thinks, to Crustaceans. The argument drawn from the Professor's former conclusion against the doctrine of the *progression of animal life* is, of course, much weakened by the result of his more complete investigation.

I may also add, that since the delivery of this Address, I have received, by the kindness of M. Desor, on his return from America, a copy of the first Part of a "Report on the Geology and Topography of a portion of the Lake Superior Land District," by MM. Whitney and Foster, United States geologists. The second Part is not yet published. The first Part contains many excellent details respecting the Drift of Lake Superior. I rejoice to find that the American geologists are engaged, with their characteristic energy, in investigating the general phænomena of the Drift. We may expect from them, ere long, important additions to our knowledge on this subject.

* See Quart. Journ. Geol. Soc. vol. vii. p. lxxvi, and p. 250.

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PART II. MISCELLANEOUS.

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

The QUARTZIFEROUS PORPHYRIES, *according to their* NATURE, *their* DISTRIBUTION, *their* RELATION *to* NORMAL STRATIFIED *and* UNSTRATIFIED ROCKS, *as well as* MINERAL VEINS. By Dr. GUSTAV LEONHARD of Heidelberg. pp. 212. 8vo. Stuttgart, 1851. With 2 Lithographs, 5 Plates of coloured Sections and 12 Woodcuts.

Die QUARZ-FÜHRENDEN PORPHYRE, *nach ihrem* WESEN, *ihrer* VERBREITUNG, *ihrem* VERHALTEN *zu abnormen und normalen* GESTEINEN, *so wie zu* ERZGÄNGEN. Von GUSTAV LEONHARD.

IN drawing the attention of our readers to this work, we may mention that it is the first attempt hitherto made to bring together the history of the porphyritic rocks and the literature connected therewith, as also to describe the various localities where the Quartziferous Porphyries have been observed, as well as their relations to other rocks, sedimentary and non-sedimentary.

The ancients, it is well known, reckoned Porphyry amongst their marbles. Pliny remarked, that "the porphyritic marble, which was quarried in Egypt, has a reddish colour." The beautiful Porphyry, so much used in the classic ages, and of which many important works of art were constructed, was derived in all probability from Upper Egypt, and not, as Rozière formerly supposed, from Mount Sinai.

Pliny also alludes to the white spots in the Porphyry, for which reason it was called *Leucosticos* or *Leptosephos*. Lucan calls the rock *Lapis purpureus*, on account of its red colour, which was peculiarly appropriate to that of Egypt.

Even in the sixteenth and seventeenth centuries, the word Porphyry was used by naturalists in the same vague and uncertain sense; it had a purely technical signification. Agricola reckoned it amongst his Marbles, under which name were at that time included all rocks capable of being polished. The artists of Italy distinguished it according to its colour, *Porfido rosso, Porfido nero, Porfido verde antico*, &c., terms of which even the most learned, as Cronstedt, Linnæus, Wallerius, Saussure, &c., have made use.

Some writers have been induced, in consequence of the great hardness of certain kinds of Porphyry, to class it amongst the precious stones (Brückemann).

The most extraordinary views respecting this rock, and particularly respecting the spots contained in it, were undoubtedly those of Buffon. According to him, Porphyry consisted mainly of the spines of *Echini*, connected by a hard, strong cement pressed close together, and which constituted the white points by which Porphyry was recognized. Each of these white spots had a black point in the centre; this represented the nerve-cavity which extends through the whole length of the spine of the *Echinus*.

The fine porphyry of Esterel attracted the attention of naturalists even in the latter half of the eighteenth century. The Swede Angerstein*, Buffon†, Saussure‡, Darluc§, and others allude to this rock. Most of these descriptions, however, are obsolete and inapplicable to the state of geological knowledge of the present day. The artists of Rome employed the porphyry of Esterel in their works under the name of *Mordiglione*.

Older naturalists, who looked upon Porphyry as of neptunian origin, assumed that "the enclosed portions of felspar" were older than the porphyry itself; that they had been already hardened. Pott—the chemist of Berlin, who died in 1799—recognized the enclosed particles or spots as "sparry." The acicular hornblende, peculiar to several kinds of porphyry, was regarded in older descriptions of the rock as "Black Schorl."

Towards the end of the eighteenth century, the word "Porphyry" acquired another and more scientific meaning. Werner applied it to the structure of the rock. He separated Porphyroid, as a general, from Porphyry, as a special or particular term. Under the first he classed those rocks, the matrix or paste of which contains single grains or crystals, which have been formed contemporaneously with the rock itself. The term "Porphyry" was restricted by him to such porphyroidal rocks as belonged to a class, the paste of which is homogeneous, and which especially contain imbedded crystals of felspar. We are indebted to Gerhard for the first most important and appropriate observation respecting this rock.

After further details of the various descriptions and classifications of different kinds of Porphyry, our author continues, p. 4:—

L. von Buch is undoubtedly one of the first geologists who obtained a clearer insight into the true nature of this rock. This is particularly evident from his observations respecting the neighbourhood of Christiania:—"We must never forget that the compact mass of all the porphyries is never a simple mineral: that its true mineralogical character, however, cannot be recognized, is due to the circumstance of our vision not being capable of making out the minute individual particles." This was written in 1808. Godon also expressed his doubt that all *Petrosilex* was one simple mineral. He separated Petrosilex into "simple" and "porphyritic."

Nevertheless the greatest uncertainty prevailed respecting Por-

* Mémoires des Savants Étrangers, vol. ii. p. 557, 1755.
† Histoire naturelle des Minéraux, vol. iii. p. 372.
‡ Voyages dans les Alpes, § 1436.
§ Histoire naturelle de la Provence, vol. iii. p. 327.

phyry. Rocks of a totally different character were confounded with it. Thus we find in a memoir on the Lead-mines of Viconago, not far from the Lake of Lugano, that the mica-slate mountain which contains the ore rests on granite or gneiss; the summit consisting of the "roche argileuse, parsémée des grains calcaires à laquelle les Allemands ont donné le nom de Feldspath-Porphyr." Soon afterwards Gerhard endeavoured to show that all Porphyry, usually subdivided into Clay-porphyry, Hornstone-porphyry, and Felspar-porphyry, invariably had Felsite for its basis.

The term "Felsite" was first used by Kirwan in his 'Mineralogy*,' to denote a substance described by Wiedemann† as "compact felspar." Klaproth observes, "I understand under the name of Felsite that mineral, hitherto called 'compact felspar,' which, when united with greenish hornblende, forms, with a crystalline structure, Greenstone, and, with a slaty structure, Greenstone-slate‡."

Gerhard says of Felsite, that it seldom forms mountain-masses, but is united with other rocks, and that in combination with hornblende, felspar, quartz, and mica it forms the various species of porphyry. He distinguishes:—1. Earthy felsite, forming the basis of all the so-called clay-porphyries (amongst these Gerhard includes Werner's clay-stone); 2. Splint-felsite, forming the basis of all hornstone- and felspar-porphyry; and 3. Laminar felsite or Labrador-stone. Adopting the clay-stone and clay-porphyry phraseology of the Germans, the French formed their *Porphyre argilleux* and *P. terreux*, the English their "Clay-porphyry" and "Clay-stone," and the Italians their *Porfido argilloso*. Brongniart considered the clay-stone as a peculiar rock and named it *Argilophyre*, subdividing it according to the colours. Haüy called it *Felspath compacte porphyrique décomposé*. Jasche described the porphyry of the district of Elbingerode on the Hartz as *Feldspath-gestein*.

Considerable progress in the knowledge of porphyry was made by d'Aubuisson de Voisins. This active follower of Werner called attention, amongst other things, to the analogies between granite and porphyry; and to the transition of these two rocks into one another, already observed by Saussure, Dolomieu, and others. It was d'Aubuisson also who maintained that the basis of porphyry was only a compact granite. He proposed that it should be called "Eurite."

After giving d'Aubuisson's description of eurite, the author continues, p. 6:—On account of the red colour of the rock which prevails in many districts (*e. g.* Thuringia, Silesia, and the Tyrol), it received the peculiar name of "Red Porphyry," an expression afterwards used by L. von Buch in another sense to distinguish it from "Black Porphyry" or Melaphyre.

Leopold v. Buch was also the first to attribute a greater importance to the presence of quartz. He directed attention to the peculiar significance of the presence of this mineral in decomposed, wea-

* Elements of Mineralogy, vol. i. p. 439.

† Bergm. Journal, 1791, p. 345.

‡ See his Chemical Enquiries into the Felsite of Siebenlehn: Klaproth, Chem. Abhandlungen, v. p. 259.

thered, or altered porphyries. "The quartz in these porphyries," he remarks in his observations on the Thuringer Wald*, "in the form of dodecahedral crystals, is a good guide to enable us to recognize the *red porphyry*, even where it no longer shows traces of its former state, and where, without the quartz, one might be tempted to confound it with the unquartziferous, *black porphyry*." For this purpose, L. v. Buch adopted the expression *Quarz-führender Porphyr* (Quartziferous Porphyry)—undoubtedly one of the best and most characteristic of the many names which have been given to this rock. Its importance in a geological point of view was recognized by most geologists; thus we have *Porphyre quartzifère*, *Porfido quarzifero*, &c. It was not, however, always adopted.

In England the word "Porphyry" was very freely used; rocks of different kinds (diorite, &c.) were thus called; so that in many descriptions it is impossible to detect the nature of the rock.

Certain quartziferous porphyries which occur in the mining districts of Cornwall as veins, partly in granite, partly in clay-slate, have been long there known under the name of "Elvans." We have in vain sought for the origin of this term in English writers. Henwood expressly says† that the etymology of the word is unknown. May it not perhaps be derived from a place called "Elvan"? Reuss says, in his 'Lehrbuch der Geognosie‡,' that porphyry occurs near Elvan, in Westmoreland.

But comparatively little importance was attached to the presence of quartz. Phillips, in his 'Outlines of Mineralogy and Geology §,' has made some attempts to distinguish the different kinds of Porphyry; and MacCulloch justly complains of the too great extension of the word "Porphyry ‖."

Notwithstanding the proposals of Gerhard, d'Aubuisson, and others, respecting the varying and incorrect ideas of hornstone- and clay-stone-porphyry, and notwithstanding the observation of L. v. Buch, that the matrix or paste of porphyries was not uniform, these expressions were maintained, because geologists wanted proper terms to distinguish Porphyry, according to its characters—crystalline and compact (Felspar), hard and brittle (Hornstone), or earthy and decomposed (Clay-stone and Clay-porphyry). We find these names both in the various elementary works on geognosy, and in the many valuable communications which we possess respecting the occurrence of this rock.

After detailing the various nomenclatures proposed and adopted by different mineralogical and geological writers, the author proceeds, p. 8:—The want or rather the great poverty of quartz at once distinguishes such porphyries from the characteristic quartziferous porphyries, without either separating them from the group of Felsite-porphyries, or, still less, uniting them with the black or Augite-por-

* Taschenbuch für Mineralogie, vol. xviii. p. 455, 1824.
† Trans. of the R. Geol. Soc. of Cornwall, vol. v. p. 27, 1843.
‡ 1805, p. 292. § Page 167, ed. 1826.
‖ MacCulloch, On the Geology of various parts of Scotland; Trans. of the Geol. Soc. Lond. vol. ii. p. 415.

phyries. To these belong certain Thuringian porphyries with little or no quartz, and which B. Cotta calls *Glimmer-Porphyre* (Micaceous Porphyry). "I must again repeat," he says, "that much of that which is generally called Melaphyre probably belongs to the *Glimmer-Porphyre*, which is often vesicular and amygdaloidal."

One of our first mineralogists has lately published a very instructive memoir "on the rocks belonging to the granitic group *." Both Porphyry and Syenite-porphyry are included in this group. Porphyry, according to G. Rose, consists of felspar, oligoklase, quartz, and mica, which form a compact matrix containing large crystals of the same constituent elements. Syenitic porphyry contains in a compact paste crystals of felspar, mica, oligoklase, and hornblende. It is only distinguished from the former by not containing quartz (or at least very seldom).

Naumann, in his 'Lehrbuch der Geognosie,' adopts another view. According to him, the felsitic porphyries form a separate group. This includes all those porphyries the paste of which appears to be a close and fine-grained mixture of felspar and quartz, which melts under the blowpipe. This paste or matrix is called felsite by Naumann, and the porphyry is called felsite-porphyry. The paste consists chiefly of the following minerals:—felspar (orthoklase) in grains or crystals; oligoklase and sometimes albite; quartz in grains or crystals; and mica. Amongst these the quartz is by far the most important, inasmuch as the distinction of "quartziferous" or "non-quartziferous" depends on its being present or not. With reference to these distinctions, Naumann admits the following rocks into the family of the Felsite-porphyry:—

1. Non-quartziferous Porphyry. The usually dark paste contains crystals of felspar, mica, and sometimes hornblende; quartz is altogether wanting, or only seldom occurs.
2. Minette. A rock consisting principally of mica.
3. Granitic Porphyry. In the composition of the paste, besides quartz and felspar, mica and perhaps a little chlorite appear to concur. The paste contains crystals of felspar, oligoklase, quartz, mica, and sometimes scales of chlorite.
4. Felsite-Porphyry (Quartziferous Porphyry). Quartz is always found in the paste or matrix, two kinds of felspar generally occur, and sometimes mica also.
5. Pitchstone-Porphyry.

It was the original object of this memoir only to describe the occurrence and conditions of the quartziferous porphyry. The author, however, found that this was not altogether practicable, on account of its close connection with some of those porphyries that contain little or no quartz. He therefore includes these also in his remarks; and, chiefly following Naumann's classification, gives to the group the general term "Felsite-porphyry." This, according to its mineralogical characters, consists of three subdivisions:—

1. Quartziferous Porphyry.
2. Granitic Porphyry.
3. Non-quartziferous Porphyry.

* G. Rose, Zeitschrift d. deutsch. geolog. Gesellsch. vol. i. p. 352 *et seq.*, 1849.

The author then proceeds to describe the characteristic features of these three subdivisions of Felsite-porphyry, commencing with the quartziferous, to which indeed his remarks are principally confined.

With regard to the mass or paste of quartziferous porphyry, he remarks (p. 18), that it has been already observed by Heim, that "in porphyry everything is extremely changeable. In the same bed the mass occurs sometimes in a coarse, sometimes in a fine-grained condition, here argillaceous and soft, there hard and producing a spark from steel*." Whoever has traversed a porphyry district must have remarked how constantly every hill, or even every rock, offers fresh varieties and new peculiarities; that the same rock appears in one place compact, hard, and close-grained, in another soft and earthy, and again in another place porous; that in one place numerous ingredients occur, which entirely disappear after a short distance. The Bruchhaus Stones, where the rock appears under more different aspects than are generally met with within so small a space, are an excellent example. At the same time in many porphyry districts, regular characteristic transitions from one to the other condition can be established; thus Credner reckons six principal varieties in the Thuringian Hills, whilst Naumann distinguishes eight mineralogically different porphyries in the neighbourhood of Wurzen, Grimma, and Taucha.

The metamorphism, mineral contents, and varied structure of porphyry are then briefly but clearly described, together with the substances into which the felspar is occasionally changed.

The changes which the felspathic substances undergo produce various results, leading to the formation of different minerals, viz.:— 1. Kaolin; 2. Lithomarge; 3. Steatite [Speckstein]?; 4. Alum. These are as fully described, pp. 28–31, as the present state of mineral analysis allows, although the origin of the talc in the speckstein has not yet been sufficiently explained.

The different conditions of the occurrence of quartz and mica in porphyries are next described (p. 35–40). Quartz occurs more regularly and systematically than either felspar or mica, and almost universally in the form of bipyramidal dodecahedral crystals, seldom transparent, and only rarely with the six-sided prisms. While quartz and felspar may be considered as the most important contents of quartziferous porphyry, mica can only be considered as a subordinate ingredient, although as such it is one of the first. It generally occurs in small scales, leaflets, or six-sided tablets.

Amongst the less important minerals which occur in quartziferous porphyries, either as nodules or in veins, the author mentions (p. 41–45) hornblende, pinite, garnet, iron-pyrites, magnetic iron, graphite, tourmaline, agate, carnelian, plasma, opal, fluor-spar, chalcedony, barytes, oxides of iron, epidote, psilomelane, gypsum, calc-spar, pinguite, chrome-ochre, native copper, &c.

The granitic and unquartziferous porphyries are next briefly described, together with the varied structure and fracture of the different porphyritic rocks (p. 45–63); after which the author points out the various localities where porphyry has hitherto been observed on

* Beschreibung der Thüringer Waldgebirges, vol. ii. pp. 44, 50.

the earth's surface, commencing with Saxony, Bohemia, and other parts of Germany, and extending to America, Egypt, and Australia (p. 64–110). To this section the author adds a list of the geological maps on which the occurrence of porphyry is noted.

The second portion of the work relates to the connection between porphyry and the stratified and unstratified formations. After alluding to the history of the subject and the opinions held by the earlier cultivators of the science, the author states (p. 111) that Hutton was the first who attempted to establish any real notion respecting the probable origin of this rock. The occurrence of granite in the micaceous slate of Glen Tilt led him to the idea that the former had penetrated the latter, and was consequently younger. He extended this theory to porphyry, and in vain attempted to introduce it among the followers of Werner. It was only after the commencement of the nineteenth century, that the idea, that porphyry and other rocks, hitherto reckoned amongst the primitive formations, had been produced by the operation of fire, acquired any credit. The journeys of L. v. Buch in Norway and Lapland, and of Hausmann in Scandinavia, had great influence in producing this result. Porphyry-dykes are first mentioned in the works of these two travellers as penetrating clay-slate and transition limestone. Equally important were the observations made by the Swedish author Strŏm, in 1812, in the neighbourhood of Freiberg. He must be considered as one of the first who opposed the then prevailing idea of the stratified nature of porphyritic masses. MacCulloch, A. Boué, and others wrote decidedly in favour of the eruptive nature of porphyry; and finally, as the author states (p. 113), we have a work, respecting the formation of porphyry, by the Mining Councillor Schmidt, who is so well acquainted with the geological relations of the Rhine district, in which he points out the many analogies between this rock and basalt, and states his conviction that porphyry has risen through the crust of the earth in an igneous, fluid state*.

During the last twenty years these views have become almost universal. In various and distant countries observations have been carefully recorded respecting the occurrence of quartziferous porphyries with stratified and unstratified rocks, the most important phænomena of which are subsequently described.

We can only briefly notice the different heads into which the author has subdivided the subject (p. 106–186).

I. Porphyry and the abnormal formations. The relations of porphyry with gneiss, mica-slate, granite, syenite, hornblende-slate, diorite, serpentine, crystalline limestone, and melaphyre; describing all the principal localities where it occurs under the different circumstances.

II. Porphyry and the normal formations. 1. The relations of porphyry with the Greywacké formations; 2. the Carboniferous system; 3. the Rothliegende or Permian; 4. the New Red Sandstone; 5. the Jurassic system; 6. the Cretaceous formations: and the relations between crystalline limestone and porphyry.

III. Plutonic and volcanic formations newer than porphyry.

* Karsten's Archiv für Bergbau, vol. vii. p. 195 *et seq.*, 1823.

1. Quartzite and porphyry; 2. Diorite; 3. Melaphyre; 4. Basalt; and 5. Pitch-stone, with porphyry.

IV. Mutual relations of different porphyries one to another. 1. Micaceous porphyry and quartziferous porphyry. This occurs in Thuringia, where the latter is almost always the youngest rock. 2. Quartziferous porphyries of different ages.

The concluding portion of the work relates to the occurrence of ores in porphyry, and the relation of the latter to metallic veins. Contrary to the opinion of former writers and authorities, recent investigations have shown that the quartziferous porphyries not only frequently contain metallic veins, but that, in many districts, they must be looked upon as the true agent in the production of ores. In Siebenbürgen (p. 187) the auriferous rock is a soft, white, argillaceous porphyry. The mountain Affinish, which rises 300 feet above Vöröspatak, consists of clay-porphyry, with many large crystals of quartz. The rock is perforated by numerous narrow crevices, which are often filled with carbonate of manganese, and also contain native gold and lead ore*. In Mexico the quartziferous porphyry near Quanaxuato is intersected by veins of calcareous spar and quartz, which also contain gold and silver.

We cannot conclude these extracts from Dr. Leonhard's work without one more quotation respecting the localities from whence the porphyries of the ancients were derived. Referring to the use of porphyry by the Romans, our author says (p. 207):—It is less generally known that the Romans also obtained porphyry from France, which was used in their works of art. In this respect the communications of Coquand and Texier are of much interest. Between the base of the Esterel group, consisting of red porphyry, and the sea, there occurs a bluish-green porphyry. It is generally called *Porphyre des Caux*. This fine stone, susceptible of the highest degree of polish, was used by the Romans to adorn the harbour of Fréjus, and, amongst the many valuable materials used to embellish and enrich the town, there is none to be compared with this bluish-green porphyry, which was used for numerous monuments (according to Coquand, also to ornament the monuments at Riez, Aix, Arles, and Orange). The stone was even transported to Rome, where, as was even the case in Fréjus, it was considered to have been obtained from Egypt (amongst other instances, Coquand mentions several columns in St. Peter's and in the Quirinal as made from the porphyry of Fréjus). It was for a long time unknown that the quarries were in the immediate neighbourhood of the town. Strangers took away specimens in the conviction that they belonged to a rock the locality of which was unknown. The old quarries are, however, still extant. They are situated in a deep valley, distant 1070 metres from the seashore. Detached blocks were here found, as well as iron wedges, driven into (and still remaining in) the cracks and fissures of the rock to facilitate the removal of large masses. An ancient vase, fragments of red earthenware, and a bronze medal bearing the head of Vespasian, found in the quarries, prove that they were worked, or had at least been opened, in the time of the Cæsars.

[W. J. H.]

* Lill v. Lilienbach. Boué, Mém. de la Soc. Géol. de France, vol. i. p. 276.

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On Fossil Rhinoceros Remains. By C. Giebel.

[Jahresb. naturw. Vereines in Halle. 1851, pp. 2–9.]

From the great abundance in which fossil bones of the Rhinoceros occur throughout Europe, there is no doubt that for a long time, fossil remains not having yet met with scientific consideration, they were abundantly collected and, mixed with other remains, were sold as the *unicorne fossile*. In my own family for a century past has the sale of the fossil Unicorn, from the gypsum-quarries of the Seveckenberg*, near Quedlinberg, been carried on with foreign travellers; and the descriptions of the bones, as handed down from father to son, tend to prove that the majority belonged to Rhinoceros. Their true explanation, however, could not have been given at this early period, as nothing had yet been known of the teeth and skeleton of the living Rhinoceros. This knowledge was supplied by Worm, who thereby afforded Grew, in 1681, the means of asserting the existence of the Rhinoceros in a fossil state. In 1668 a fragment of an upper jaw had been exhumed at Chartham near Canterbury; in this the form and position of the orbits were evident, which enabled Grew to refute Somner's assertion † that this fragment of skull had belonged to the Hippopotamus ‡.

The next determination of fossil Rhinoceros bones we meet with is half a century later. Numerous bones had been found near Herzberg, in the Hartz, which, from their great size, had been taken for those of the Elephant. Hollman compared them with the skeletons of the Elephant and Hippopotamus, and conjectured, on account of their striking dissimilarity to both, that they belonged to the Rhinoceros. To confirm his conjecture he transmitted a tooth to Meckel, who, during his stay in Paris, compared it with the Rhinoceros, afterwards described by Buffon and Daubenton, and recognized its perfect identity §. A mass of material, far richer than had yet been collected in England and Germany, was found by Pallas in the Peters-

* [For an account of these quarries by M. Giebel, see Jahresb. *loc. cit.* p. 15 *et seq.*—Transl.]

† Philos. Transact. 1701.

‡ [See also Owen's Brit. Foss. Mam. p. 331.—Transl.]

§ Akten Götting. Gesellschaft, vol. ii. 1752.

burg Museum, which had been brought together from the most distant parts of the Russian empire. He undertook the management of this Museum in 1758, and his attention was immediately directed to four Rhinoceros skulls, the most perfect of which he described in 1761*. Pallas soon afterwards visited Siberia, and there found that remarkable relic, the carcase of a Rhinoceros, on the banks of the Willuji, an affluent of the Lena. This was in December 1771, and two years afterwards† he gave a description and figure of some of its parts, together with that of a perfect skull discovered at the Baikal Sea. To the latter he also devoted a second memoir in the 'Acta' for 1777, and, in the 'Neuen Nordischen Beiträgen' of 1779, he noticed other Rhinoceros bones discovered in Kasan. During this time, in Germany also, some notice had been taken of the fossil Rhinoceros. Zückert illustrated with some fine drawings‡ the bones that had been exhumed from the Seveckenberg in 1728 by former members of my family and preserved in the collection of Privy Counsellor Müller at Berlin. Soon afterwards, 1782–84–86, Merk's important letters appeared; the first of which contains a description of a skull and several parts of a skeleton from the banks of the Rhine, in the Darmstadt district. In the second letter was mentioned the discovery of another skull near Worms, on which Collini also wrote a memoir§,—another skull from near Cumbach,—two teeth from Weissenau, and a third from Strasburg. The last letter refers also to the bones dug up near Cologne and at other places in Germany. Although not conversant with osteology, yet, from a careful comparison of the fossil remains with which he was acquainted, Merk recognized two specifically distinct Rhinoceroses as having once existed in Germany, both of which also were decidedly distinct from the two living species which were then known to naturalists. Still earlier, Camper‖ had pointed out the difference between the species with, and the species without incisor-teeth, and had entered into a discussion with Pallas on the presence of incisors in a Siberian skull; the examination subsequently (in England) of a Sumatran skull with incisors convinced him of this specific difference.

These were the materials on which Cuvier worked, and on which his faculty of classification was brought to bear. In 1795 and 1797 he gave his views on the peculiar species with lengthened skull and two horns. In the beginning of this century he read an elaborate memoir on both the fossil and the living species of Rhinoceros, of which he distinguished four or five. But notwithstanding Cuvier's satisfactory exposition of the difference of the species, Faujas St. Fond, in his 'Essai de Géologie,' 1801, asserted that the greater length of the skull and the ossification of the nasal septum in the Siberian Rhinoceros were conditions characteristic merely of age, and that the animal differed not from the species now living in Central Africa. No refutation of this view appeared, and it was forgotten. In the

* Act. Petersb. Acad. vol. ii. † Act. Petersb. Acad. vol. xvii.
‡ Beschäft. Naturforsch. Freunde in Berlin, vol. ii. 1776.
§ Abhandl. Mannheim. Akad. vol. v.
‖ Act. Petersb. Acad. 1780.

'Mémoires du Muséum' (vol. vii. 1806), Cuvier gave a full account of the osteology of the species of Rhinoceros then known to him; and here the Siberian Rhinoceros was recognized by distinct and important characters, as a peculiar species. Hitherto this had been known as the "Siberian Rhinoceros." In his 'Archæologia,' and a year later in his 'Natural History,' Blumenbach gave it the specific name of *Rh. antiquitatis*, and Fischer, in his 'Zoognosia,' 1814, changed it to *Rh. tichorhinus*, which latter has been accepted by Cuvier and all later writers.

Cuvier's extensive researches facilitated the specific determination of fossil remains of the Rhinoceros, and these were everywhere more carefully studied. The next important discovery took place in 1811, in the Vale of the Arno, a report of which was given in a letter from Philip Nesti to Targioni Tozetti. Cortesi also described*, in 1819, a nearly perfect skeleton which he found in the Subapennine Hills, in the Placentin. In that Part of Cuvier's 'Ossemens Fossiles' published in 1822, this species received the name of *Rh. leptorhinus*, and together with it also the incisor-teeth figured by Merk, besides a similar tooth from Avaray, were determined as belonging to *Rh. incisivus*; and a *Rh. minutus*, from Moissac, was, from its smaller size, less positively determined. The fine skull from Montpellier, to which Marcel Serres, in the 'Journal de Physique,' 1819, had given the specific appellation of *Rh. monspessulanus*, was referred by Cuvier to *Rh. tichorhinus*. Whilst the last volume of the 'Ossemens Fossiles' was in the press, 1825, Cuvier received, through Schleiermacher, drawings of the skull and jaw discovered near Eppelsheim, by which he was confirmed in his opinion of the near alliance of the *Rh. incisivus* to the living Sumatran species. After the publication of Cuvier's osteological researches, the number of the species increased so much in a few years, that when Pander and D'Alton, in their beautiful work on the Skeletons of the Mammalia, endeavoured to reduce the number, they were far from meeting with general approbation. Henceforth scarcely a year passed without the announcement of new localities for fossil Rhinoceros bones being discovered. Then came that unfortunate æra of uncriticised Palæontology, 1830–43, which produced a whole host of new Rhinoceroses.

Immediately after the publication of the 'Ossemens Fossiles,' 1825, Baker and Durant noticed the discovery of fossil Rhinoceros remains in the tertiary beds of the Sub-Himalayas, which, ten years later, they ascribe to *Rh. unicornis fossilis*. In 1828 Clift and Buckland mention this species, from the Irawady, and subsequently Cautley and Falconer, from the Sub-Himalayas, under the name *Rh. angustirictus* or *sivalensis*. Croizet and Jobert in 1828 pointed out one of the fossil bones from Auvergne as having belonged to a slender and long-legged species, *Rh. elatus*. On some unworn teeth of *Rh. tichorhinus*, from the Loës of the valley of the Rhine, Bronn made his genus *Cœlodonta* †, which after a short existence again disappeared. In the same year Harlan ‡ instituted his *Rhinoceroides Alleghanensis*, from a

* Saggi Geologici. † Jahrb. f. Min. u. s. w. 1831.
‡ American Monthly Journal of Geology.

fragment of upper jaw, found in Pennsylvania, which bears not the slightest resemblance to that of the Rhinoceros, and indeed may well be a work of art. Other specific names were produced by Kaup for the Eppelsheim remains, together with Short Notices, in the 'Isis,' 1832, in Von Meyer's 'Palæontologica,' 1832, and in the 'Jahrbuch,' 1833. Amongst these was *Rh. pachyrhinus*, soon after re-named *Rh. Schleiermacheri*, founded on two perfect skulls, jaws, and other parts, and, according to Cuvier, belonging to *Rh. incisivus*. *Rh. hypsilorhinus* was again transferred to the last-named species, and *Rh. Goldfussi* was suppressed. The single incisor of *Rh. leptodon*, from Wiesbaden, appeared to belong to *Rh. Schleiermacheri*, and the four-toed, hornless *Rh. incisivus* served as the type of the new genus *Aceratherium*. In 1834 the Third Part of Kaup's 'Descript. Oss. Foss.' appeared with a full description of the genus *Rhinoceros*. *Rh. Schleiermacheri*, *Rh. leptodon*, *Rh. minutus*, and, under *Aceratherium*, *Rh. incisivus* and *Rh. Goldfussi*, were referred to as individual species. The same year was further distinguished by De Christol's Memoir on the History of Rhinoceroses. With the aid of new materials this writer undertook a critical examination of Cuvier's species. *Rh. tichorhinus* retains incisors in the under, and probably in the upper jaw; *Rh. leptorhinus* is dissolved, its skull being given to *Rh. tichorhinus*, the bones of its extremities to *Rh. incisivus*. The peculiar characters which Cuvier could not recognise as satisfactory in the remains of the *Rh. incisivus* he had at his command, are pointed out in the Montpellier skull by De Christol, who thought that on account of these newly found evidences of specific character it should bear the new name *Rh. megarhinus*. In the same year also Cortesi discovered a second skeleton in the Placentin; and, mistaking the humerus and femur, and the form of the tip of the jaw and of the last upper molar, found in it new generic characters, the naming of which, however, by the advice of Blainville, was postponed. On the other hand, the well-known deposit of Sansan afforded numerous bones which Lartel, also in 1834, distributed under the names of *Rh. brevimaxillaris*, *Rh. longimaxillaris*, and *Rh. quadridigitatus* or *inermis*. The description of these did not appear until 1836 *, and then with some alterations of names—the species with four-toed fore-feet and three-sided incisors appearing as *Rh. tetradactylus longimaxillaris*, the smaller one, with slender legs and shorter jaws, as *Rh. tetradactylus brevimaxillaris*; with a third, unnamed species.

In Germany, in 1835–39, G. F. Jäger was, like Kaup, busily engaged in multiplying the specific names in his 'History of the Fossil Vertebrates of Würtemburg.' The species he there gives are—*Rh. Kirchbergensis*, established on two upper and one lower molar,—acknowledged by Kaup, and by him changed to *Rh. Merkii*, identified by Owen as *Rh. leptorhinus*, and by Blainville placed with *Rh. incisivus*, —*Rh. chærocephalus*, identified with *Rh. incisivus* by Jäger himself, who appears to have chosen this probably only as a provisional name, —*Rh. molassicus*, which, according to the notice of Jäger's work in

* Bulletin Soc. Géol. de France, vol. vii.

the 'Jahrbuch,' 1837, rests only upon the fragment of an upper molar,—*Rh. Steinheimensis*—according to Blainville this agrees somewhat with *Rh. minutus*, and he refers its teeth to those of the Palæotheres and Lophiodons. Lastly, we must mention the *Tapiroporcus*, which Jäger established on the milk-teeth of the Rhinoceros.

In the last ten years criticism has been as busy as species-making. Owen's excellent work on the Fossil Mammalia of England threw great light on *Rh. tichorhinus* and *Rh. leptorhinus* by his comprehensive description of these species. The Monography of the Rhinoceros, in Blainville's great work on Mammalia, also appeared about the same time. The result of three years' labour, with the help too of a prodigious mass of material, does not satisfy this critical observer. He points out the existence of two living species in Africa and of three in Asia. Of the fossil species he regards as well established the *Rh. tichorhinus*, *Rh. leptorhinus*, *Rh. unicornis fossilis*, and *Rh. incisivus*, the males of which last species have been described, according to the different conditions of age, as *Rh. Goldfussi*, *Rh. Schleiermacheri*, *Rh. Merki*, *Rh. minutus*, and *Rh. elatus*; and the females of which have no horn.

To the new species have been added in the course of the last ten years *Rh. tapirinus*, by Pomel *, from the tertiary beds of the Puy de Dôme, and by Raulin, 1848, from the same place, *Rh. brachypus*, and *Rh. tetradactylus* from Sansan.

The discovery of a very young lower jaw with the sockets of incisor-teeth misled me into establishing a genus—*Hysterotherium*, which I withdrew on obtaining a more perfect jaw, that enabled me to recognize it as belonging to a young *Rh. tichorhinus*. The exhumation of nearly all the parts of a skeleton of the *Rh. tichorhinus*, numerous specimens of various bones, as well as the skeleton from Nordhausen, now in the Museum of this place, has enabled me to examine this species more particularly than had been hitherto done. But Brandt's Memoir on the *Rhinoceros tichorhinus*, just commenced, in the 'Memoirs of the Petersburg Academy,' which will contain not merely a richer mass of material, but indeed valuable information on the soft parts, renders a more detailed account of my researches unnecessary.

[T. R. J.]

On Borings in Search of Rock-salt, *in* Switzerland.
By P. Merian.

[Bericht Verhandl. Naturf. Gesellsch. Basel, 1851, ix. pp. 41–44.]

M. Köhly, Engineer, of Biel, who has been perseveringly engaged for many years in the search for Rock-salt in the interior of the Jura, has commenced boring at the village of Wysen, Canton Soleure, near the Lower Hauenstein.

Wysen stands on the great development of Muschelkalk which composes the northern Jura, and which extends uninterruptedly from

* Bulletin Soc. Géol. 1844.

the neighbourhood of Baden, by Habsburg, Dentschbüren, Kienberg, Läufelfingen, Oberdorf, and Reigoldzwyl as far west as Meltingen in the Canton of Soleure. To the south of this fine range of Muschelkalk, which indicates the principal line of elevation in the northern Jura, the high inclinations and inversions of the strata commence, which contrast strongly with the more horizontal bedding which prevails to the north. The first bore was put down at Ablecken, west of Wysen, near the bend in the new road to Hauenstein, the strata consisting of nearly horizontal beds of compact Muschelkalk, the Friedrichshall limestone of Alberti. At a depth of 240′ (Swiss measure) white, grey, and black gypsum was passed through, which continued to the depth of 480′, frequently alternating with black slaty clay, bituminous limestone, and hornstone. The water at this depth contained 4 per cent. of salt. At the end of June 1848, at a depth of 498′, variegated marl with gypsum was bored through, perfectly indistinguishable from the marls of the Keuper. In the beginning of July, somewhat deeper, small silicified *Ammonites*, belonging to the upper beds of the Gryphite-limestone, were found in the boring tools. It follows, therefore, that, notwithstanding the horizontality of the beds at the surface at the spot where the bore is put down, there is a total inversion of the masses, which has thrown the Muschelkalk above the Keuper and the Gryphite-limestone. The horizontality of the Muschelkalk is in fact confined to this locality; for through all the rest of its range the bedding is greatly disturbed, and exhibits great faults and flexures within short distances.

These results are in accordance with those obtained in 1834 from the borings at Oberdorf, in the western prolongation of the Muschelkalk of Wysen, where at a depth of 580′ the Keuper marls were reached under the Muschelkalk*. Similar borings at Kienberg, in Soleure, to the east of Wysen, on the same Muschelkalk range, have also failed; but the author is not acquainted with further particulars.

These discouraging failures did not deter M. Köhly from boring afresh in 1850, to the eastward of Wysen, at the brook which flows past Zeglingen. The spot chosen was in a valley, closed in to the north by the Wysenberg with its highly-disturbed beds of Muschelkalk, and to the south by the Wysenfluh, on whose escarpment from the base to the summit the whole series of beds from the Muschelkalk to the Great Oolite is exhibited. Up to June 1850 the beds bored through were the following:—

	Feet.
Porous limestone (upper dolomitic division of the Muschelkalk)	152
Compact Muschelkalk (Friedrichshall limestone)	156
Coarse white and yellow marls, gypsum, and clay	78
	386

M. Köhly writes on the 12th November, 1850, that he had reached 532′, in a smoke-grey gypsum, alternating with black saline clay, sometimes bituminous, and with grey and yellow marl and limestone.

While the present paper was in the press, the 200th Number of the

* Bericht, ii. p. 51.

Journal of the Naturalists of Berne appeared, in which M. Thurmann announces the interesting fact, that in the borings also made by M. Köhly in 1828, at Cornol near Pruntrut, after passing through the Keuper at the surface, and a remarkable thickness of Muschelkalk beneath it, unquestionable Oxford Clay with its characteristic fossils was reached at a depth of 1100′.

This is a still more remarkable instance of displacement than those observed at Wysen and Oberdorf. Cornol moreover is in the western prolongation of the great line of elevation, which from Baden to Meltingen has brought the Muschelkalk to the surface, but further westward, in the Valley of the Vorburg, near Delsburg and near Cornol, the Keuper only.

M. Köhly has also bored near Grellingen, six miles above Basle, close to the right bank of the Birs. The strata consist of compact beds of the Great Oolite, with a southern dip of about 10°. Higher up the valley is surrounded by rocks of the Coralline Limestone. The work was undertaken with the view of boring through the Great Oolite, the entire thickness of the Lower Oolite, the Gryphite limestone, the Keuper, and the Muschelkalk, down to the saliferous marls. The depth to be bored was consequently very considerable. According to M. Köhly's estimate, he first sank through 270′ of compact oolite, then dark grey marls, which by falling in greatly impeded the boring. It was frequently necessary to put down iron pipes, to take them up again and replace them by new. The consequence was, that it was impossible to be certain in what strata the workings were being carried on. At last iron pipes were put down to a depth of 1200′, and the boring-hole cleaned out. At 1283′ variegated marls with gypsum, clearly of the Keuper series, were reached, and continued to 1413′, the depth attained by the borings at the latest intelligence, 12th November, 1850. M. Köhly thinks that he passed through the Muschelkalk at the depth of between 900′ and 1200′; then, that he reached an inverted mass of that formation, and lastly, again found himself in the Keuper. These sinkings, however, do not appear to M. Merian to justify this conclusion. In this gentleman's opinion there is no proof of an abnormal succession of strata, by which, as the depth increased, newer beds were found under older, especially since in this view of it the thickness of beds between the Oolite and Keuper would be considerably greater than where they are exposed to day in that neighbourhood.

[J. C. M.]

On the GEOLOGY *of* PARAGUAY. By P. MERIAN.

[Bericht Verhandl. Naturf. Gesellsch. Basel, 1851, ix. pp. 51–53.]

PARAGUAY is upon the whole a flat country, especially in its southern part near the confluence of the Paraguay River with the Parana. In this quarter no rock is exposed, but merely silt, underlaid by clay and sand. After the inundations, culinary salt (which is collected for domestic purposes), mixed with sulphate of soda and sulphate of

magnesia, is found on the mud. Concretions of iron-stone are sometimes found in the sand. Further to the north and east, towards Angostura and Asuncion, the country becomes more hilly. The hills are principally formed of a fine-grained grey sandstone, in horizontal beds or with a slight dip to the north: it is sometimes compact enough to be used for a building-stone, and quarries have been opened in the hills near Emboscada. The sandstone contains many beds of conglomerate, resembling Nagelfluh. In several places between Asuncion and Villarica, magnetic iron is found in the sandstone, which has partly passed into oxide of iron and hydrated peroxide, but still strongly attracts iron-filings: nodules of clay-iron-stone are found in the streams. This sandstone is of tertiary age. Near Asuncion it contains a thick-shelled oyster, resembling *Ostræa canadensis*, Lam. Near the same town, bones of fossil Mammalia have been found, which according to Rengger belong to the *Megatherium*. They were found at a moderate depth in a sandy loam, which distinctly belongs to the Diluvium and not to the underlying sandstone.

Higher up the Paraguay, north of Tavego, occurs a fine-grained calcareous sandstone, of a yellow and grey colour, which is used for whetstones.

Limestone has lately been found on the left bank of the Paraguay, from 25 to 30 leagues north of Villareal; this is the only spot in Paraguay where it is found *in situ*.

Near Itapua on the river Parana there occurs a round lump of calcedony, of a honey-yellow colour, and filled with quartz; which makes it probable that trap exists to the east of the extensive tertiary formation. Similar fragments of calcedony and quartz are found in the streams of the forest-country, or Montes, opposite to the Sierra de St. Jose. A fragment found near Yhu consisted of a compact granular quartz or quartzose sandstone. Lastly, the streams also bring down little bits of a coarse-grained granite with flesh-coloured felspar. Our traveller * has not reached the range of mountains whence these specimens were derived.

[J. C. M.]

* M. Rengger, whose collection of rock-specimens has been presented to the Basle Museum.

TRANSLATIONS AND NOTICES

GEOLOGICAL MEMOIRS.

On Graptolites. By Prof. Dr. H. B. Geinitz.

[Zeitschrift der Deutschen Geolog. Gesellsch. vol. iii. p. 388–390.]

In a brief notice of his work on Graptolites*, Dr. Geinitz gives the results arrived at after a critical examination of all the species of Graptolites published up to the end of 1851.

The number of real species Dr. Geinitz limits to 60. The following is a synopsis of the genera, with observations.

Family Graptolithinæ, Bronn.

Genus 1. Diplograpsus, M'Coy.

Syn.—*Diprion*, Barrande; *Petalolithus*, Suess.

Characters.—Biserial, with a solid axis.

Number of species, 17.

Genus 2. Nereograpsus, Geinitz.

Syn.—*Nereites*, *Myrianites*, *Nemertites*, &c., Auctorum.

Characters.—Biserial. The stem having no central axis, or a very soft one.

Number of species, about 7. Type. *Nereites Cambrensis*, Murchison.

Note.—In specimens from Saalfeld I saw the cell-mouths distinctly.

Genus 3. Cladograpsus, Geinitz.

Characters.—With two branches, or forked.

Number of species, 7. Types. *Graptolithus Murchisoni*, Beck, and *Graptolithus ramosus*, Hall.

Genus 4. Monograpsus, Geinitz.

Syn.—*Monoprion* and *Rastrites*, Barrande; *Graptolithus*, Suess.

Number of species, 28.

* 'Die Versteinerungen der Grauwackenformation in Sachsen und den angrenzenden Länden-abtheilung. Heft 1. Die Graptolithen. 58 pp. 6 Lith-Plates. 4to. Leipsic, 1852.'

Genus 5. RETIOLITES, Barrande.

Syn.—*Gladiolites*, Barrande.

Characters.—Biserial; the upper surface covered with a network; having a superficial central axis.

Number of species, one.

Note.—This genus differs in its characters so very much from the rest, that it would be injudicious to name it afresh on the plan on which the foregoing have been named, at the expense of the generic appellation given by M. Barrande.

Observations.—The generic name *Diprion* having been laid aside, *Monoprion* also, for the sake of uniformity, should be changed to *Monograpsus*.

It is not advisable that the name *Graptolithus* should be applied to any group of the *Graptolithinæ*; for the *Graptolithinæ* collectively will long be spoken of as "Graptolites," as is the case with "Trilobites," "Terebratulæ," and "Ammonites." I have separated *Graptolithus gracilis*, Hall, *G. Hallianus*, Prout, and *Lophoctenium comosum*, Richter, from the family of the *Graptolithinæ*, and placed them with the *Sertularidæ*. M. Barrande's genus *Rastrites* is so nearly connected with *Monograpsus* through the *R. triangulatus*, Harkness, which was first a *Rastrites* and then a *Monograpsus*, that I have placed them together. *Birastrites* also occur, answering to *Diplograpsus*.

In all *Graptolithinæ* the lower or basal extremity is the thinnest end of the stem, in an upward or forward direction from which cells or cell-germs are placed.

The *Graptolithinæ* lived, like their existing allies, the *Virgulariæ*, either free in the sea, or attached by a foot-stalk to the mud of the shore; some, perhaps, remained attached only for a short time.

The surface of the Graptolites in the slate is frequently converted into Talc, which has generally been taken for a silicate, and in some Graptolite-schists traces of jet are present.

[T. R. J.]

On the FLORA *of the* TRANSITION ROCKS.

By Prof. Dr. H. R. GOEPPERT.

[Zeitschrift Deutsch. geol. Gesell. 1851, vol. iii. p. 185–207.]

IN announcing that he hoped soon to be enabled to publish the results of his researches in the Flora of the Transition Rocks, Dr. Goeppert observed that in the term "Transition Formation" he includes all the different strata older than the Coal Formation,—the newer Grauwacke of Silesia and Saxony, which is evidently the analogue of the Millstone Grit or Sandstone underlying the Coal-measures in England, the Posidonomya-schist of the Harz and Nassau, the Carboniferous Limestone, the older Rhenish Grauwacke or Spirifer-sandstone, and analogous rocks in North America, generally known as Devonian rocks, and lastly the Silurian Formation. In all these

remains of Plants have been found. Dr. Goeppert's work comprises:—

1. A sketch of the distribution of the "Transition" strata in all parts of the globe.
2. The Plant-remains of the Transition formation and their state of preservation.
3. The Transition rocks of Silesia. These require a separate notice on account of the great number of their fossil plants—nearly the half of those hitherto known.
4. A systematic description of the "Transition" plants.
5. Palæontological and geological results.
6. Explanations of the plates, of which forty (4to and folio), illustrative of these fossil plants, are already finished.

The Professor then gives a general view of the species systematically arranged, together with their stratigraphical relations, and the localities where they have been found. This is succeeded by the following geological view of the "Transition" flora, the species being arranged according to the formations.

I. SILURIAN FORMATION.

I. Lower Silurian.

1. Potsdam Sandstone.

Scolecolithus linearis*, *Haldeman.*

2. Calciferous Sandrock.

Palæophycus tubularis, *Hall.*
—— irregularis, *Hall.*
Buthotrephis antiquata, *Hall.*

3. Bird's Eye Limestone.

Phytopsis tubulosa, *Hall.*
Phytopsis cellulosa, *Hall.*

4. Trenton Limestone.

Palæophycus rugosus, *Hall.*
—— simplex, *Hall.*
Buthotrephis gracilis, *Hall.*
Buthotrephis succulenta, *Hall.*
Sphærococcites Serra, *Sternb.*
—— dentatus†, *Sternb.*

5. Utica Slate.

Sphenothallus angustifolius, *Hall.*

6. Hudson River Group.

Palæophycus virgatus, *Hall.*
Buthotrephis subnodosa, *Hall.*
Sphenothallus latifolius, *Hall.*

* [See Mr. Logan's Observations on the *Scolithus*, *supra*, Part I. p. 196. Other Canadian Fucoids are mentioned by Mr. Logan, *loc. cit.* p. 197 (a reticulated form), and p. 203 (a bilobed form).—Transl.]

† These two species, first described by Adolph Brongniart as *Fucoides*, were found in limestone strata near Quebec, a district regarded as Trenton Limestone by the American geologists, who do not, however, mention these fossils. Perhaps, after all, they are not Plants, but Graptolites, which indeed I think is far from being improbable. [Both are Graptolites. See Geinitz's 'Graptolithen.'—Transl.]

II. Upper Silurian.

1. Medina Sandstone.

Harlania Hallii, *Goeppert.* Fucoides auriformis, *Hall.*

2. Clinton Group.

Chondrites antiquus, *Brongn.* sp.

II. DEVONIAN ROCKS.

Europe.	America.
Older or Rhenish Grauwacke (Spirifer-sandstone).	**1. Hamilton Group.**
Haliserites Dechianus, *Goepp.*	Knorriæ, sp.
Chondrites antiquus, *Brongn.* sp.	Sagenariæ, sp.
—— Nessigii, *F. A. Roem.* sp.	**2. Chemung group.**
Sagenaria, sp.	Sphenopteris Halliana, *Goepp.*
Delesserites antiquus, *Goepp.*	Sagenaria chemungensis, *Goepp.*
Asterophyllites Roemeri, *Goepp.*	Sigillaria Vanuxemi, *Goepp.*
Dactylopteris Stiehleriana, *Goepp.*	

Cypridina Schist.

Confervites acicularis, *Goepp.* Sphærococcites lichenoides, *Goepp.*

III. CARBONIFEROUS LIMESTONE.

Asterophyllites elegans, *Goepp.*
Calamites transitionis, *Goepp.*
Zygopteris tubicaulis, *Goepp.*
Gyropteris sinuosa, *Goepp.*
Sphenopteris refracta, *Goepp.*
Cyclopteris dissecta, *Goepp.*
—— Bockschii, *Goepp.*
—— frondosa, *Goepp.*
——, sp. (fragment).
Lycopodites acicularis, *Goepp.*
Cardiocarpon punctulatum, *Goepp.* and *Berger.*
Lepidodendron squamosum, *Goepp.*
Noeggerathia obliqua, *Goepp.*
Stigmaria ficoides, *κ. Anabratha, Goepp.*
Protopitys Buchcana, *Goepp.*
Araucarites Beinertianus, *Goepp.*

IV. POSIDONOMYA SCHIST*.

Anarthrocanna stigmarioides, *Goepp.*
*Bornia scrobiculata, *Sternb.*
Sphenopteris pachyrrachis, *Goepp.*
Hymenophyllites, sp. (fragment).
Odontopteris imbricata, *Goepp.*
Cyclopteris, sp. (fragment).
*Lepidodendron hexagonum, *Goepp.*
Sagenaria depressa, *Goepp.*
*Sagenaria Veltheimiana, *Sternb.* sp.
—— Roemeriana, *Goepp.*
—— geniculata, *F. A. Roem.*
Knorria polyphylla, *F. A. Roem.*
—— Jugleri, *F. A. Roem.*
—— Goepperti, *F. A. Roem.*
—— megastigma, *F. A. Roem.*
Stigmaria ficoides, λ. lævis, *Goepp.*

* According to F. A. Roemer the newer grauwacke beds alternate with the Posidonomya-schist. Von Dechen, however, does not take this view. Dr. Goeppert, therefore, separates these formations, and has marked with an asterisk the species that are common to the two.

V. NEWER GRAUWACKE OF THE HARZ, SAXONY, AND SILESIA.

(The equivalent of the lower beds of the English Coal Formation.)

The species marked † occur also in the Carboniferous Limestone, those marked †† in the Coal-measures, and those marked * in the Posidonomya-schist.

Equisetites radiatus, *Brongn.* sp.
†Calamites transitionis, *Goepp.*
††—— cannæformis, *Schloth.*
—— Roemeri, *Goepp.*
—— dilatatus, *Goepp.*
—— tenuissimus, *Goepp.*
—— obliquus, *Goepp.*
—— variolatus, *Goepp.*
—— Voltzii, *Brongn.*
Stigmatocanna Volkmanniana, *Goepp.*
Anathrocanna approximata, *Goepp.*
—— tuberculosa, *Goepp.*
—— deliquescens, *Goepp.*
*Bornia scrobiculata, *Sternb.*
Asterophyllites pygmæus, *Brongn.*
—— Hausmannianus, *Goepp.*
Sphenopteris Beyrichiana, *Goepp.*
—— anthriscifolia, *Goepp.*
—— imbricata, *Goepp.*
††—— obtusiloba, *Brongn.*
††Hymenophyllites Gersdorfii, *Presl*, sp.
——, sp. (fragment).
††—— dissectus, *Brongn.* sp.
Trichomanites grypophyllus, *Goepp.*
—— sp. (fragment).
††Neuropteris Loshii, *Brongn.*
Odontopteris Stechleriana, *Goepp.*
Cyclopteris flabellata, *Brongn.*
—— tenuifolia, *Goepp.*
††Cyatheites asper, *Goepp.*
Pecopteris stricta, *Presl*, sp.
Noeggerathia æqualis, *Goepp.*
—— distans, *Goepp.*
Noeggerathia ovata, *Goepp.*
—— abscissa, *Goepp.*
Lycopodites Stiehlerianus, *Goepp.*
*Lepidodendron hexagonum, *Goepp.*
*Sagenaria Veltheimiana, *Sternb.* sp.
††—— aculeata, *Mart.* sp.
†—— acuminata, *Goepp.*
—— remota, *Goepp.*
—— concatenata, *Goepp.*
——, sp. (fragment).
Ancistrophyllum stigmariæforme, *Goepp.*
Dechenia euphorbioides, *Goepp.*
Didymophyllon Schottini, *Goepp.*
Megaphytum Kuhianum, *Goepp.*
—— remotissimum, *Goepp.*
—— dubium, *Goepp.*
—— Hollebeni, *Unger.*
Knorria imbricata, *Sternb.*
—— longifolia, *Goepp.*
—— acicularis, *Goepp.*
—— Schrammiana, *Goepp.*
Stigmaria ficoides, *Brongn.*
——, β. undulata, *Goepp.*
——, ε. sigillarioides, *Goepp.*
——, ζ. inæqualis, *Goepp.*
——, θ. elliptica, *Goepp.*
Sigillaria minutissima, *Goepp.*
—— Voltzii, *Brongn.*
—— densifolia, *Brongn.*
—— undulata, *Goepp.*
Araucarites Tschikatscheffianus, *Goepp.*

Results.—Though I dare predict, says the Professor, that within a few years after the publication of my work a great number of additional species will be discovered in the Transition series (fifty have been observed by myself in Silesia alone, a very limited area in comparison with the extent of this formation), yet I will venture to draw some conclusions from the phænomena of which we are already cognizant.

1. Land-plants are not found in the oldest or Silurian strata, as the very elaborate researches of the American geologists prove. It is to be hoped that equally careful investigations will before long settle this question for Europe also. Marine plants, and especially Fucoids, constitute the first form of vegetation on our planet. Yet we cannot affirm, although some of these plants, for example, *Harlania Hallii*, appear to have possessed a very peculiar organization (with respect to which further researches can alone enlighten us), that this earliest vegetation was really so different from the existing marine flora, as

may be said of the terrestrial vegetation of the Coal Period, as compared with that of the present day.

2. In America, as in Europe, the first land-plants appear to have a very isolated distribution, and belong to known families and genera of the Coal-flora (*Lycopodiaceæ*, *Filices*, and *Asterophyllites*) mingled with marine plants (Fucoids), which last belong to certain strata, as those of the Cypridina-schist, perhaps exclusively.

3. In the Carboniferous Limestone Plants are already numerous, and Fucoids wanting, at least they have not yet been discovered. To the families that have appeared earlier, are now added Ferns in greater variety, as also *Stigmariæ*, *Sigillariæ*, *Noeggerathiæ*, and *Coniferæ*, the last partly without annual rings. With the small number of Ferns the prevalence of the *Neuropteridæ* is to be remarked—as is also the case in the succeeding formations. Next to this family come the *Sphenopteridæ*. The *Pecopteridæ* appear for the first time in succeeding strata.

4. The flora of the Posidonomya-schist, in respect to genera and species, is not really separable from that of the younger Grauwacke, which I have parelleled with the Millstone-grit of England,—indeed in different districts, as in the Hartz and Silesia, they have several species in common. In this formation (comprising both the above), Fucoids are altogether wanting. *Calamites* and Ferns, especially the *Neuropteridæ* and *Sphenopteridæ*, predominate. The *Pecopteridæ*, however, are represented by two species only. This formation has only one species (*Sagenaria acuminata**) in common with the more ancient Carboniferous Limestone, whilst there are no less than six common to it and the younger Coal-formation, viz. *Calamites cannæformis*, *Sphenopteris obtusiloba*, *Hymenophyllites dissectus*†, *Neuropteris Loshii*, *Cyatheites asper*, and *Sagenaria aculeata*.

5. The total number of species (inclusive of nine distinct forms, too fragmentary, however, to be characterized) as yet found is 121, belonging to the following families:

	Fucoides	24
	Equisetes	14
	Asterophyllites	4
Filices.	Sphenopterides	16
	Neuropterides	10
	Pecopterides	3
	Noeggerathiæ	5
	Lycopodiaceæ	36
	Sigillarieæ	5
	Stigmariæ	1
	Coniferæ	3
		121 Species.

* [This species is omitted, perhaps by mistake, from the list of Carboniferous Limestone plants. On the other hand, *Calamites transitionis* is especially indicated as belonging both to this formation and to the "Younger Grauwacke." There would, therefore, appear to be two species common to the two formations.—Transl.]

† [*H. Gerdorffi* makes a seventh species common to the two formations: see the list.—Transl.]

All the more important families of the Coal-formation, with the exception of the *Cycadeæ* and *Palmæ*, which are rare even in that formation, are here represented. Hence it necessarily follows, as Brongniart has also maintained, that in the long period, from the first appearance of vegetation on the earth to the Red Sandstone overlying the Coal, no real change of the vegetation is observable in the different strata.

Whether the successional development of plants, here adduced as self-evident, is to be further confirmed, the future will show. For my part, I cannot doubt it. Sharpe and Bunbury find in Portugal extensive coal-beds with land-plants accompanied by Silurian fossils. But this requires further investigation. [T. R. J.]

Coal-beds *of the* Larzac. By M. Rouville.

[Acad. Scien. Montpellier, Nov. 1849; and Leonhard u. Bronn's Jahrb. f. Min. 1851, p. 466.]

The Larzac belongs to the numerous plateaux, known as the Cousses, which stretch north and south from Espalion (Aveyron) to Clarmont (Hérault). These plateaux generally consist of a horizontally-bedded limestone, cut up by fissures and valleys, in which the towns of Milhau, Mende, &c. stand. In ascending from Lodève to Mont Caylar, the Bunter Sandstone of Soubis is first traversed, then a dolomitic bed, which represents the white lias of the English geologists or the infra-lias of Leymerie. On this lie the Fucoid-marls noticed by Dumas. Next follows another dolomitic deposit; the Oxfordian limestone and the Coral-rag, but slightly developed, here predominate. The Plateau de la Cavalérie comprises four or five groups of carboniferous deposits (La Cavalerie, La Liquille Céral, Saint Georges de Lusençon) which are situated on the Oolite with Fuci. There are two kinds of coal, only one of which—the glance-coal—is used in the forges. The organic remains that have been found belong to the genera *Cyclas*, *Paludina*, *Mytilus*, and *Cyrena*. There are no traces of plant-remains. This deposit of coal is of much interest, as it appears to indicate a true Weald-formation [Weald-gebilde] in the midst of the Jurassic series. [T. R. J.]

On Pea-Iron-Ore. By P. Merian.

[Bericht Verhandl. Naturf. Gesellsch. Basel, 1851, ix. pp. 44–47.]

Alexander Brongniart's view, that the Pea-ore [Bohn-erz] of this neighbourhood (Basle) belongs to the Tertiary age is clearly incorrect; since, wherever the beds of pea-ore occur in their original position, they are always covered by the Tertiary deposits. Besides, the geographical extension of the pea-ore beds on the western declivity of the Black Forest between Basle and Freyburg supports the view

that they belong to an older order of things than the tertiary. The different divisions of the Jura-formation, the Keuper, and the Muschelkalk in this neighbourhood are greatly broken up and dislocated. Wherever the upper division of the Jura, which in this quarter is the Coralline Limestone, shows itself, the pea-ore in greater or lesser beds is sure to be found, the Coralline Limestone always forming its base: while the Tertiary formations spread themselves indifferently over all the divisions of the Jurassic, Keuper, and Muschelkalk formations. It is clear from this that the pea-ore is connected with the Jura-formation, which has been broken up and dislocated after the deposition of the pea-ore and previously to the deposition of the tertiaries. The few fossils which are found in the pea-ore beds, and even in the ironstone itself, as well as in the hornstone and jasper-concretions, all belong to the Coralline Limestone, e. g. *Cidaris Blumenbachii*, Goldf., *Astræa*, *Foraminifera*, &c. If it is asserted that these animals did not live at the period of the deposition of the pea-ore, but that they existed previously, and that their remains were by some metamorphic process changed into iron-ore, &c. (which is very possible), still it is certain that these fossils, when in their original habitat, are never accompanied by any of a later date.

The surface of the Coralline Limestone, where it forms the immediate substratum of the pea-ore, is worn down and eaten into by remarkable winding cavities. It is usually accompanied by variegated clays and pure quartz-sand, materials not found in the Jurassic formation, and which must either have been introduced together with the pea-ore, or been formed out of the previously existing rock by those chemical influences from which the pea-ore resulted. The Coralline Limestone itself, where in immediate contact with the pea-ore, has peculiar properties, as for instance, a very distinct vitreous fracture. A remarkable instance of this kind is seen at Roppe, near Befort, where an extensive bed of pea-ore is worked partly below ground and partly at the surface in a cavity of a limestone which probably is the Coralline. The limestone is furrowed on its surface with long grooves, at the end of each of which lies a concretion of pea-ore, which fills up and closes the groove. These appearances are all satisfactorily explained by the theory long ago put forth, and now perfected by M. Gressly, which refers the origin of the beds of pea-ore to the chemical effects of hot springs, containing iron and other substances in solution, poured out upon the limestone probably about the close of the Jurassic period. Dr. C. Burckhardt, who looks upon this explanation as the most natural, remarks that, from Burg and Klein-Lützel to Laufen, the pea-ore is found accompanied by fossils of the so-called Sequanian system, a subdivision of the Jurassic system, which immediately reposes on the Coralline Limestone.

[J. C. M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

Notice of Prof. B. STUDER's 'GEOLOGY OF SWITZERLAND.' 1st vol.* *The Central Alpine Chain and the Chain immediately to the South.*

[Leonhard u. Bronn's N. Jahrb. f. Min. u. s. w. 1852. 2 H. p. 231 *et seq.*]

THE abstruse problem of the elevation of the great masses of our continents has of late years excited lively interest. In the earlier days of geology, an isolated observer applied himself to the study of a small portion of the Alps, the district of Mont Blanc or of St. Gothard for instance; the age of the Jura or of the Apennines was then not so well known as that of many of the most distant quarters of the globe is at the present day: while now we see a constantly increasing number of labourers, struggling to arrive at a thorough knowledge of this range. The Alps are encircled by a perfect army of observers, who every summer penetrate into their recesses, and add something to our information respecting them.

This work of Prof. Studer derives its chief importance from the circumstance that he has himself visited almost all the spots described, some of them repeatedly, and not a few in the company of M. Escher. Where the observations of others are introduced, reference is made to the work quoted. The author gratefully acknowledges the valuable assistance he received from M. Escher, who in the frankest manner placed at his disposal the results of his own researches.

The introduction is devoted to a general view of the Apennines, the Alps, and the Jura.

The Alps follow one another in their order of juxtaposition: the Ligurian, or first Alpine group to the W. of Genoa: the Maritime, in which the Alpine type begins to show itself more distinctly by a second "central mass" (or nucleus) of crystalline slates: the Cottan and Grecian Alps: the Alps of Oisans, which display a "central mass" more clearly than any which Studer has travelled through,—in no other locality can it be so distinctly seen that the felspathic rocks, which form the nucleus, have been upheaved after the deposition of the overlying Neptunian formations, and have forced through the latter, throwing them off on every side, and changing their structure; the Red Alps (*Les Rousses*), well known in the records

* Geologie der Schweitz. Erster Band. pp. 485. 8vo. Berne, 1851. With woodcuts and a Geological Map.

of French mining operations: the Western Alps: the Swiss Alps; and, lastly, the Eastern Alps.

After this introduction follows the first division of the work, which is devoted to the central zone of the Alps.

Alpine granite, gneiss, and crystalline schists.—The determination of the age of the granite of the Alps, which Jurine thought to establish by the introduction of the name Protogine, is the boundary-line between old and modern geology. The production of these crystalline schists by the metamorphosis of sedimentary matter, and the explanation of these processes agreeably to the laws of chemistry and of physics, together with the old question whether these rocks have their origin in water, or in heat, or in both conjointly, are looked upon by the author as problems standing out foremost in the field of geologic inquiry for solution, now as much as fifty years ago, and which his own experience leads him to believe will not speedily be solved.

To this subdivision belong the "central masses" of the Aiguilles Rouges, of Mont Blanc, of the Finsteraarhorn, of St. Gothard, and the Alps of the Valais, respectively: afterwards, those of the Tessine Alps, the Adula, Sureta, and Maritime chains, of the Bernina and of the Selvretta, and lastly that of the Oetzthal Ferner are considered.

The Alpine granite, or protogine, of the central mass of the *Aiguilles rouges* frequently puts on a gneissose structure. At the end of the last century considerable mines of argentiferous galena and of copper were opened near Servoz. In the workings near Promenaz lead and copper mixed with baryta occur. Granite in the form of veins has penetrated not only the crystalline schists but also the limestone formations. The southern flank of the *Dent de Morcles* gives indications, which deserve to be followed up.

In theorizing on the elevation of the Alps, the similarity of the central granite nuclei to trachyte domes is always striking, however anomalous the conditions are proved to be on closer examination. These granite masses appear to have been raised up over long fissures, as a trachyte cone over a central cavity; the whole mass, in a solid or soft state, having been actually forced upwards; or, early sedimentary deposits, penetrated by fluids or gases, have been thereby modified in condition and increased in volume so as to swell up to the mountain-heights here spoken of.

In the nucleus of Mont Blanc as in that of the Aiguilles Rouges protogine prevails, especially on the eastern side, and from thence towards the centre. No geologist who examines the rents in these rocks, their slender pinnacles, and the abrupt precipices which surround the Mer de Glace at the Montanvert and the glaciers lying behind it, can believe that the present form of Mont Blanc is that which it originally bore. One might almost believe that the mountain after its first formation had been elevated to its highest point in the district of the upper Tacul glacier, and that by a subsequent sinking of the mass the deep glacier-valley extending from the Mer de Glace to the summit of Mont Blanc had been occasioned. Mont Chétif and Mont de la Saxe rise like two vast pillars on the sides of the

rocky defile which leads from Cormayeur to the Allée Blanche and the Val Ferret. The view of the Mont Blanc range from this height exceeds in sublimity that from Mont Cramont. Not far from the Mont de la Saxe at the 'Trou des Romains' can be seen an old mine of argentiferous galena, worked at an unknown period. This is far from being the only mine in the circuit of Mont Blanc, some of which have been abandoned, while others are still in operation: on the heights of Ardon magnetic iron-ore is now being wrought in a talcose schist.

The "central mass" of the Finsteraarhorn, in spite of its much greater extension and its abnormal direction, presents several rather unexpected analogies with the two groups just described. The relation of its beds to the upheaved limestone and schist formation is the same as that observed in Savoy, but on a greater scale and more distinctly exposed. On the northern boundary of the mass, the most remarkable instances of the contact of crystalline with sedimentary formations occur: the deep ravines have made a clean section through their point of contact, and penetrated into the very heart of the mountain. On the Bach Alp above Leuck, a wedge-shaped mass of gneiss must be regarded as intrusive into the limestone which encircles it. The romantic Gasteren-Thal is admirably calculated for studying such relations. The numerous contortions of the limestone- and schist-beds, as seen on the rocky walls of the Altel and the Doldenhorn, together with the conversion of the lower strata into marble and dolomite, prove that here, as in Savoy, the limestone is older than the felspathic rocks which underlie it. On the eastern declivity of the Tschingel glacier the granite also appears beneath its covering of limestone. Similar conditions may be observed in the Grindelwald, in the deep section of the mountain by which the lower glacier descends. The background of the Urbach valley, and especially the crest of the Urbach-Sattel between Tossenhorn and Gstellihorn, also give very instructive lessons bearing on the same question. The most striking fact is the high inclination of the beds of gneiss which dip to the south. A cursory observation would lead to the belief that the gneiss was older than the limestone, and that its present outline parallel to the beds of the latter was due to the disruption of the mass of both; but this opinion cannot be maintained if we only cast a glance on the other side of the valley on the mountains of the Laubstock and the Tristenstock.

The pass of the Grimsel long ago excited Saussure's curiosity by the external characters of the rock.

The rounded spherical forms (*roches moutonnées, rundhöcker*) of the gneiss and granite in the valley, and the hummocky and cylindrical shape of the rocks which hem it in, are seldom seen so marked or so persistent. The contrast between the rounded shape of these rocks and the sharp angles of the high mountain-crests is seldom so distinctly marked as in the chain which surrounds the Aar-Grund on the Grimsel and the glacier of the Vorder-Aar. It requires close observation to satisfy oneself that the rounded bosses really consist of the schistose gneiss which passes uninterruptedly into the upper

gneiss. M. Studer is of opinion that the hypothesis of erosion by glacier-ice, propounded by Agassiz and his followers, is the most simple and the most in accordance with nature.

The mass of St. Gothard approaches nearer to that of the Finsteraarhorn on the south than the Mont Blanc group to the Aiguilles Rouges. It is far from being so considerable in linear extension as the group of the Finsteraarhorn, though more so than the Mont Blanc group, which last however is broader and loftier. Immediately above the Hospital are well-marked mica-slates; and above, towards the Gemsboden, distinct gneiss. The region of the granite proper of St. Gothard begins at the level of the Gothard lakes. On the southern declivity towards Val Tremola, gneiss again occurs, followed by hornblende rock and dolomite. The well-known fan-shaped structure of St. Gothard extends as far east as the granite can be traced.

This locality is celebrated for the variety of its minerals. Daubrée has justly observed, that there is a remarkable resemblance between the substances found in the "central masses" of the Oisans, of Mont Blanc, the Finsteraarhorn, and St. Gothard, so as to give independent support to the view of these mountains having a very close internal relation. There are moreover analogies between many of those mineral substances and the products of existing volcanos, which, from the great difference between the rocks containing them, could not have been anticipated. From such comparisons the chemist draws conclusions, which it is to be hoped will throw light upon the obscure origin of these nuclei. New investigations, however, and comparisons of the different localities, their geological relations, and the condition of the matrix, will probably be needed for the safer foundation of such speculations; and on this point we may shortly expect valuable information from M. Wiser of Zurich, who has done so much for the study of Swiss mineralogy.

The "central mass" of the Alps of the Valais appears to be a passage from the lofty fan-shaped rocks lying next to the exterior chain and the gneiss formation of greater horizontal extension forming the inner range. A fan-like structure is not clearly shown in the gneiss and mica-slate, and a disposition to symmetric arrangement is wanting. Beds of limestone and marble are more abundant; serpentine and gabbro pierce through them; and on the southern side of the group occurs a syenitic granite, such as is seldom seen but on the southern margin of the chain. The characteristic of this central mass is the intimate relation of its rocks with those of the schistose zone which flanks it, arising from both having undergone the same flexure and from the mineralogical passage of the one rock into the other.

Talcose gneiss and green slates together with serpentine and gabbro form all the mountains on both sides of the Ferpecle glacier and the Col d'Erin. In the principal mass of that remarkable and inaccessible mountain, the Mont Cervin, the formations are distinctly divided by their colour, as at the Aiguilles Rouges. In many parts of these mountains, and notably on the heights of the Matterjochs, may be seen most complicated relations between gneiss, serpen-

tine, slate, and limestone: Saussure devoted more than three days to the study of them.

In the region of the Alps of the Tessine the gneiss and mica-slate have almost entirely lost their alpine character. A well-characterized gneiss predominates, and next to that mica-slate is an important member of the group. The latter rock abounds in many kinds of concretions, especially at the Cima di Zambro, at the foot of the P. Forno, at Sponda, &c. &c. The limestone and slate mass of the Levi- and Dever-Alps is in the strike of the green slates and limestone, which may be followed from Saas to Zwischbergen, and is doubtless their prolongation. The rocks at Naret, at the junction of the romantic valleys of Bavona, Peccia, and Campo la Torba, are extremely disturbed. In the deep ravine of Val Bavona, on the eastern base of the Gran Pasodon, hitherto unknown to the geologist, the gneiss which surrounds the Suena Alp on its western side overlies the dolomite belonging to the calcareous zone, and is intertwisted with it and with schists, while further on the gneiss is clearly seen as the fundamental rock of the range.

The Alps of the Adula range present a very unusual character. The longitudinal and transverse valleys seem to have exchanged their usual conditions. Distant as they are from the axis of the Tessine Alps, their remarkable elevation *en masse* proves them to have been disrupted from the latter.

Closely as the Tessine Alps are connected with the Adula range, they are still more nearly related to the gneiss which spreads out from Schams to the Rofla and to Ferrara, and which reaches its greatest development in the Sureta Alps with their snowy pinnacles surrounded by glaciers. The pass of the Splügen gives great facilities for studying this group. To the west rises the noble pyramid of the Tambo Horn, consisting of beds of gneiss dipping east. With these are associated in the background of the Toga Alp talcose and micaceous slate, hornblende slate, and quartzite, mostly of a decomposing quality. The main road from the Splügen, following the romantic pass of the Rofla, penetrates into the central nucleus of the group. The grey micaceous and calcareous schists which have prevailed from Splügen, begin at Suvers to give way to chlorite slate and talcose gneiss, alternating with white marble. On the road from Pignen to Nezza, for about five hundred metres above the bottom of the valley, are seen, horizontally disposed, slates forming the foundation of a vast wall of white marble and grey limestone. The Despin Alp above Zillis is an enclosed circular basin [Thal-Kessel], the background of it rising to the lofty peak of the Curves. On the west a plateau of limestone and dolomite shuts in the basin, leaving only a narrow exit for the waters from the mountain. In the lower part of the valley there were formerly many mines of argentiferous galena and of copper pyrites, which are found in talcose gneiss accompanied by large crystals of felspar. More than a dozen deserted mines can be counted along the edge of the stream, which is precipitated over many cataracts, and along the rocky descent of the mountain towards Nezza.

The crystalline slates which appear between the groups mentioned and the next zone to the south cannot readily be described, or sub-

jected to a general classification. The group of the Bernina, with its gneiss and mica-slate, forms the central mass, occupying all the space between Ober-Engadin and the Val Camonica, the serpentines of Val Malenco, and the limestones of Ortles. It is remarkable for the height of its peaks, the beauty of its glaciers and snow-fields, and the crystalline constitution of its rocks. Nowhere in these districts does the gneiss appear in such force, and the ice-mountains which reach to the Bernina road are among the most considerable which the Alps exhibit. Unlike all the "central masses" described, the Bernina is almost completely surrounded by a circle of granite, hornblende rock, and serpentine. One might well be tempted to recognize in this mass the lever that has here elevated the gneiss to so unusual a height. The main road over the Bernina leads from the heights round the lakes more to the eastward, past the Motta and the Mont Rosa. On the north bank of the Lago Bianco a dark-green rock resembling serpentine prevails; and gneiss on the steep declivity towards the ravine of the Motta and the descent to Mont Rosa. The granite of Mont Brusio only appears in the form of a considerable bed.

The nucleus of the Selvretta in many points reminds the observer of the "central mass" on the exterior margin of the middle zone: in other respects it has its own peculiar characters, like each of the other groups. A fan-like structure is observable; the alpine granite forming the axis of the fan, the crystalline slates stretching over the limestone rocks, &c. On the other hand, the gneiss over a great part of the group is replaced by a great development of hornblende slate. Passing over Fluella we have an excellent view of the relations of the western fan-shaped rocks.

Finally, the mass of the Oetzthal Ferner resembles that of Selvretta: gneiss and mica-slate penetrate like wedges into the Bündtner Alps. In the loftiest southern portion two fan-like series of mica-slate can be recognized.

This general description of the mountains is followed by a more or less detailed account of the various rocks which compose them;—granite, hornblende rock, serpentine and gabbro, green slate, grey slate, limestone and marble, dolomite, gypsum, verrucano, quartzite, and red sandstone: their occurrence in each particular spot is enumerated, and their characters described. We shall quote one or two of these observations.

With regard to serpentine and gabbro, it is said,—the question is not yet settled whether serpentine, and the gabbro which frequently accompanies it, are to be looked on as plutonic masses, which have caused the protruded rocks to pass into grey and green slates; or whether they are to be regarded as the last stages of the metamorphosis of the slates. The author is of opinion that unprejudiced judgments will give the preference to the latter hypothesis; though he candidly admits that it is open to more objections than the former.

We have often taken occasion to speak on the doctrine of metamorphism, so popular of late years. Far from being opposed to geologic transformations, we are of opinion that *within certain limits*

the doctrine is well-founded; but its arbitrary extension is suspicious. Authors too frequently indulge themselves in theories not reconcileable with our present notions, in the hope that they may hereafter be made to agree. In the Alps, where it is impossible to deny that metamorphism on a great scale has taken place, it is often difficult even to surmise how and whence the metamorphism has arisen. This will be admitted by all prudent and inquiring observers.

The "green slates," in their first and most extensive stage of development, are dark- or mountain-green clay-slate, with more or less disposition to a scaly or crystalline-foliaceous structure.

The "grey slates" are a dark-grey clay-slate, hard, and sometimes indeed not effervescent, with their surfaces often glittering with narrow plates of mica, &c.

In the second division of this Part, the author treats of the zone to the south, next to the central zone. Val Trompia, Val Seriana, Val Brembana, the lake of Como, and Brianza, with the country to the west, are described. In this portion the porphyry and granite, the formations of the older limestone and dolomite, the newer limestone, the flysch and tertiary formations, are considered.

[J. C. M.]

On the THREE SUCCESSIVE FAUNAS, *distinguished by their peculiar* TRILOBITES, *in the* LOWEST PALÆOZOIC ROCKS. By M. J. BARRANDE.

[Leonhard u. Bronn's N. Jahrb. f. Min. u. s. w. 1852, 3 H. p. 257–266.]

THE limits of the successive faunas of the earlier palæozoic periods appear to me to be well and naturally defined by means of the vertical distribution of the Trilobite families. Thus, 1. The First Fauna [Urfauna], which, everywhere that we meet with it—in Bohemia, England, Sweden, and Norway, consists almost entirely of Trilobites; and of these, the genera that characterize this fauna are also peculiar to it, viz. *Paradoxides*, *Conocephalus* (= *Calymene*, Angelin), *Olenus*, *Ellipsocephalus*, *Sao*, &c. Only one of these genera (the *Agnostus*), and that under different specific forms, passes on to the Second Fauna. Moreover, all the Trilobites of the Urfauna are distinguished by the great development of the thorax in proportion to the pygidium.

This fauna is not represented in Russia, France, the United States, and Ireland; where, however, the Lower Silurian groups are much developed. Nevertheless, sooner or later, indications of this fauna may be discovered in other countries than those above-quoted. In England, even, it was discovered but a few years since, and there only in two isolated spots in the Silurian region, viz. in the Malverns, where Professor Phillips first found *Olenus*, and in North Wales, where the Officers of the Geological Survey* have since discovered *Olenus* and *Paradoxides*† in the slates of the "Trappean group."

* [Later particulars respecting the palæontology of these lowest fossiliferous rocks were given by J. W. Salter, Esq., of the Geological Survey, in a paper read before the British Association at Belfast, 1852.—TRANSL.]

† [The locality, however, of this is not certain. See foregoing Note.—TRANSL.]

These slates are analogous to the Olenus-slates of the Malverns, and both rest on the azoic masses of the Harlech and Barmouth sandstone*. They are also altogether similar to the series (my Group C.) to which since 1846 I have referred the Urfauna of Bohemia. The fauna of Angelin's Regions A. and B.† (a slate and a limestone bed, one resting on the other) consists of *Olenus, Paradoxides, Conocephalus* (= *Calymene*, Angelin), &c., and evidently corresponds to the Urfauna of Bohemia and England. Lastly, the verbal communications with which Professor Boeck of Christiania favoured me last summer, enable me to recognize in Norway a fourth instance of this First Trilobite Fauna, resting immediately on azoic rocks.

It is very remarkable that in these four different countries this First Fauna is altogether distinct from the next succeeding fauna, not a single species being common to the two. The other organisms that accompany the Trilobites of the Urfauna are rare, and, on the whole, little characteristic, as they differ in the different countries. Thus I have in Bohemia *Orthis Romingeri* and three *Cystideæ*, amongst which is *Lichenoides priscus*. In England there are the *Lingula Davisii* of the Lingula-flags of Wales,—a doubtful form allied to *Eurypterus*,—and some indistinct remains of *Graptolites*, which I have seen in the Museum of the Geological Survey in London‡. What forms accompanied the Trilobites in the Urfauna of Sweden, I do not yet know. In any case, it is probable that, as in Norway and the other two countries, but few fossils occur, as there has been no notice of them as yet.

Thus, in each of the four regions here spoken of, Trilobites seem almost alone to have constituted the Fauna of the First Period; and this character of the Urfauna is the more worthy of notice, as it forms a striking contrast to the manifold composition of the next succeeding fauna.

2. The Second Fauna is that of my Group D. This also possesses peculiar genera, as *Asaphus* (= *Isotelus, Symphysurus, Hemicrypturus, Niobe, Megalaspis*, &c.), *Trinucleus, Ogygia, Remopleurides, Placoparia, Zethus, Amphion, Æglina, Dionide*, &c.; besides others, whose maximum development is here attained, as *Illænus* and *Ampyx*, and some, viz. *Harpes, Bronteus, Cheirurus, Phacops*, &c., which have their greatest development only in the Third Fauna. In general the genera more or less peculiar to this Second Fauna (*Asaphus, Ogygia, Æglina, Dionide, Illænus*, and even some species of *Trinucleus*), have a very reduced thorax, with a large pygidium,—strongly contrasting with what we have seen in the First Fauna. It is also to be remarked that the *genera* here reach their numerical maximum, although that of the *species* is not attained until much later. The Second Fauna is connected with the Third by a small number only of common species.

The several classes of Molluscs, *Cephalopoda, Brachiopoda, Acephala, Pteropoda*, &c., have already numerous representatives at this Period, which, however, have a very unequal geographical distribution.

* See also Bulletin Soc. Géol. France, 2 ser. 1851, p. 208 *et seq.*

† Palæontologia Suecica, Lief. 1.

‡ [*Vide supra*, p. 31, note.]

For instance, the *Orthocerata* with large siphuncle, which are so abundant in America, Russia, and Sweden, are altogether wanting in Bohemia, France, England, and Ireland. On the other hand, the majority of the Trilobite genera characteristic of this fauna, as *Illænus*, *Trinucleus*, and others, are found in nearly all the above-mentioned countries. The Trilobites, therefore, in this Period furnish the most general and safe characteristics for the vertical and horizontal boundaries of the Group. In Bohemia we can subdivide the Group D, which comprises this Second Fauna, into several well-characterized series (*d*1, *d*2, *d*3, *d*4, *d*5), which, however, are still connected by a large numerical proportion of common species.

In England this fauna is recognized in the Llandeilo (= Bala) group and the overlying Caradoc sandstone. In Sweden the Second Fauna comprises, in vertical range, Angelin's two Regions C and D; it is the same fauna also that in the district of St. Petersburgh extends from the blue clay to the limestone, inclusive. In France the greater part of the Silurian series belongs to this same Period, and I have identified several of the Trilobites with those of the Bohemian Group D, as *Acidaspis Buchi*, Barr., and *Dalmannia socialis*, Barr. In Portugal also this fauna is found in the Oporto district; and my friend De Verneuil has shown it to exist in Spain, from whence he has brought specimens of *Calymene Tristani*, Brongn., *Placoparia Tournemini*, Rou., *Illænus Lusitanicus*, Sharpe, and others.

In the United States this Second Fauna has very great superficial extent. It alone has furnished all the fossils described by Hall in the 1st volume of the 'Palæontology of New York.' All the Trilobites figured in this work have their analogues in the Second Fauna of European countries, with the exception of *Triarthrus*; whilst, on the other hand, several European types characteristic of this fauna are still unknown in America. It would, without doubt, be very difficult to persuade the geologists of the New World that they have not yet discovered in their extensive region the representatives of the First Fauna, before-mentioned. Time, however, will bring this about, together with the gradual but certain extension of these views. In Bohemia, England, and Sweden we have the succession of the First and Second Faunas well proved by the stratigraphical relations of the beds that respectively comprise them. The actual proof of this superposition in Europe leads to the conclusion that, if the First Fauna exists in America, it must be found in the deposits beneath those of the Second Fauna, and therefore must be sought for under the Potsdam Sandstone, with which the Second Fauna commences.

3. The Third Fauna, characterized by the Trilobites, commences at the base of the Upper Silurian division. Almost all the genera of the Trilobites that compose it pass up from the Second Fauna, but are here represented by different and peculiar specific forms, having special characters strikingly in contrast with those of the lower group. Thus all the species of *Illænus* of the Third Period are recognized by their *Bumastus*-like appearance. All the *Brontei* have fifteen ribs on the pygidium, whilst those two species belonging to the Second Fauna (*Br. laticauda*, Wahl. sp., and *Br. Hibernicus*, Portl. sp.) have only thirteen. The *Cheiruri* want the frontal margin, which those of the

Second Fauna possess. Although in the Upper Silurian division the number of the genera is barely half as great as in the Second Period, yet the numerical maximum of the species is found at the base of this group, as already noticed by Murchison. This great development is strongly contrasted with the very limited geographical surface, compared with the wide extent of the Second Fauna, which is occupied, especially in Europe, by the Third Fauna.

We shall find, however, a like contrast between the vertical extent of these faunas, the Second Fauna comprising groups of deposits of very great magnitude in proportion to those of the Third. This is shown in my ideal section of the Silurian rocks of Bohemia in the Bulletin, Soc. Géol. France, Jan. 1851. In England the whole Upper Silurian Division is very limited; in Sweden it is represented by Gothland; in Russia, by the Oesel Island and a few other patches; in France, by the district of St. Sauveur le Vicomte and of Feuguerolles, which are but little islands in the Silurian area. On the whole however, the Third Fauna, although vertically and horizontally confined in narrow limits, is characterized in Europe by its richness, not alone in Trilobites, but also in species of all classes of Mollusca.

In America, on the other hand, the Third Fauna occupies (according to De Verneuil) at least quite as much extent as the Second.

The succession of these two faunas is clearly shown in England by the succession of their respective deposits, and still more clearly in Bohemia. The boundary-lines which divide them in the British Isles have been precisely indicated by Murchison, who has also pointed out the same in Sweden, Russia, &c.; and De Verneuil has recognized them in America. But in none of these countries is the exact limit so sharply drawn as in Bohemia, where an outburst of trap, spreading over the surface of the Silurian basin, has at once cut off the whole Second Fauna; this Period, therefore, being separated from the Third Fauna by an azoic plutonic horizon. With the exception, therefore, of the outlying "colonies*," which have conditions peculiar to themselves, there is scarcely to be found in the whole of this district a single fossil common to the two successive faunas. This condition having resulted from local causes, as just mentioned, it is not likely to be so clearly indicated in other places, and in England especially we have a considerable number of known species passing over from the one to the other division. What exact conditions obtain in other districts, I do not know, the requisite information on the subject being still wanting; but in all cases we may regard the Second and Third Faunas as constantly separate and independent.

It only remains therefore for us to determine the upper limit of the Third Fauna. I am not, however, fully prepared to point out any absolute line of demarcation, from want of sufficiently extensive observations, especially in districts where the observer can at once survey a considerable succession of true Silurian beds overlaid by well-characterized Devonian rocks. America will without doubt some day furnish the data required to solve this question, which all European districts still leave unsettled.

This is certain, that in Sweden, Bohemia, and France, at the base

* *Vide infra*, p. 37.

of the stratigraphical division corresponding to the Third Fauna, a very surprising analogy of all the fossils is observable, and there are even a great number of species common to all these districts. But the higher we ascend the series, in each district respectively, the number of these analogous and common species diminishes more and more, as if the connexion between the Silurian seas of this period had gradually been interrupted, and disunited basins only ultimately remained. Thus the *Homalonoti*, which characterize the Ludlow series in England, are unknown in Bohemia; and, on the contrary, a great part of my Third Fauna is not represented either in England or Sweden. In Bohemia, however, the constant predominance of the Trilobites clearly indicates the continuance of the Silurian period. They are accompanied by *Brachiopoda, Gasteropoda*, &c., some of which are again found in analogous, if not identical, forms in the, so-called Devonian, deposits of the Sarthe Department, in France, and partly also of the Rhine districts and the Hartz. These facts, resting on recent discoveries, which I have found to be confirmed by the examination of my friend De Verneuil's fine collection, give rise to some uncertainty as to the position of the horizon in Europe dividing the Silurian from the Devonian System. In England only this uncertainty does not exist, where the Tilestone beds have been regarded as the limit of the Upper Ludlow series.

For my part, I am inclined to look for the establishment of this as yet undefined boundary in the consideration of the vertical distribution of the Trilobites. First, I would remark, that the genus *Calymene* never reaches the true Devonian formation. The *Calymene tuberculosa*, Salter, is quoted by him from the Upper Ludlow beds, in England, but does not occur higher up. In Bohemia I find the *Calymene interjecta*, Corda, in my Group G, but no higher. In America *Calymene platys*, Green, is quoted from the sandstone of Schoharrie, which has been called Devonian, but De Verneuil refers to this with some doubt, and possibly the geological place given for this fossil may be erroneous, since Green says in his description that it was found in a travelled block. We know that remains of the genus *Calymene* (as defined by Emmerich in his Dissertation, 1839) have [not]* been found in the Devonian rocks on the Rhine, in the Hartz, &c. To this altogether negative character I will add a positive one, viz. the occurrence in all Devonian districts of the *Pleuracanthus*, or species of *Phacops* with the pygidium armed with teeth (*Ph. punctatus*=*Ph. arachnoides*, *Ph. stellatus*, *Ph. laciniatus*, *Ph. callitelos*, &c.), a group that occurs in no well-recognized Silurian rocks, whilst it is found in all Devonian countries,—in Devonshire, France, Spain, on the Rhine, in the Hartz, &c. The oldest formation in which the *Pleuracanthus* occurs is the Spirifer-sandstone or Older Rhenish Grauwacke of F. Ad. Roemer. This then, according to my view, is the base of the Devonian System, and should be grouped with it, and not, as some think, with the Silurian System.

By the consideration of the Trilobites alone I have arrived at this conclusion, to which also F. Ad. Roemer was led by the consideration

* Query "wie eine," a misprint for "keine."

of the whole of the fossil remains of this period, among which *Pleurodictyum* played as important a part as the Trilobites. Other fossils, belonging to different classes of Mollusca, may be added to the foregoing as aids in establishing the boundary-line between the two successive systems, and of these F. Ad. Roemer's work enumerates already a considerable number.

I am far from affirming that this boundary is absolutely true, or that there are no species common to the two systems thus bounded; indeed I am aware of a considerably large number of Silurian species that reappear in the Devonian System, but they are always very few in comparison with the Devonian forms.

Generally, however, no such limit can be absolute, since nowadays it would be difficult to carry out as a general principle, that each fauna was destroyed in one and the same instant over the whole earth's surface. Destructive accidents of such a kind, if they have ever happened, could operate only on a limited surface, as for instance in Bohemia: here they destroyed the First and Second Faunas, whilst nothing of the kind is seen in Sweden, although both of these faunas exist there and are easily distinguishable.

Having thus traced out a sketch of the three great Silurian Faunas, as I regard them, I leave to others, better informed on the subject than myself, the task of subdividing in like manner, if it be possible, the Devonian System. Professor F. Ad. Roemer has already furnished an interesting work on this subject, and thereby laid the foundation for further researches, which must indeed prove difficult and wearisome, since much depends upon the authentication of the parallelism and general relations of local stratigraphical groups in districts very far apart. As regards the Silurian System, we can, I think, avoid all such controversy, as we assume, with Murchison, that groups of strata are only local subdivisions, the discrimination of which is dependent on the peculiarities of each district. Thus the presence or absence of limestone is sufficient to give rise to very perceptible differences in the vertical distribution of the fossils even in districts lying very near to one another. If we compare widely separated countries, as Europe and America, the difference of climate alone is sufficient to account either for the total absence of identical species, or for their different position in the vertical series; although the two groups of strata, conformably to the mutual analogy of all generic and specific forms in other parts of the world, comprise one and the same great fauna. Existing nature affords us in this respect the most convincing proofs. Disregarding the stratigraphical groups and subdivisions, it appears to me that we can arrive at great results, that have a universality and certainty more advantageous for science, than the partial and more or less uncertain and assailable conclusions to which we may be led by the comparison of the subordinate groups, or by attempting to show their exact contemporaneity by means of single species, the appearance or disappearance of which on the whole earth's surface is in such case assumed to have taken place at the same instant.

These questions, which I have here only slightly touched upon, are

of great importance; and I intend to treat of them fully in a treatise "on the succession and relation of contemporaneous Silurian faunas in different parts of the world." I am still, however, in want of important materials requisite for the accomplishment of the work.

[T. R. J.]

On the "COLONIES" *in the* SILURIAN FORMATION *of* BOHEMIA.

By M. J. BARRANDE.

[Leonhard u. Bronn's N. Jahrb. f. Min. u. s. w. 1852, 3 H. p. 306.]

M. BARRANDE'S "Colonies*" consist of the local appearance of his Third Silurian Fauna (Group E, belonging to the Upper Division) within the region of the Second Fauna (Group D, belonging to the Lower Division). The Colonies are of small extent, being confined, both vertically and horizontally, in very narrow limits. The strata of which they consist are intercalated in Group D, with a strike and dip conformable to the rest of the group†.

To show how closely these Colonies, intercalated in the Lower Silurian, are connected with the fauna of Group E (Upper Silurian), it is sufficient to point out that of the sixty-three species as yet found in them, thirty-seven again occur in the Third Fauna, although otherwise these two Silurian divisions (Upper and Lower) have scarcely a species in common.

M. Barrande explains these local appearances, of one fauna amidst a second, by the supposition of an immigration of organisms from another region into Bohemia, where they remained a short time, *i. e.* as long as the conditions that favoured their immigration continued favourable for their existence there. The character of the strata of these Colonies is also peculiar. During the continuance of the Colonies the deposits consisted of Graptolite-schists with calcareous nodules, identical with those subsequently forming Group E at the base of the Upper Division, and strongly contrasting with the quartzites peculiar to Group D.

After the sudden and total extinction of the Second Fauna (Group D) by the trap-eruptions which covered the whole surface of this Silurian basin, the fauna of the Colonies, with their peculiar graptolite-schists and calcareous nodules, once more appeared, and constitutes M. Barrande's Third Fauna, characterizing the lower limestone-group, E, that forms the basement-beds of his Upper Silurian Division.

Among other important considerations to which these phænomena must necessarily give rise, M. Barrande points out that, by aid of the Colonies, we have evidence of the existence (probably in the north-east of Europe) of a fauna which, had it not supplied Colonies to the Bohemian district previously to its subsequent development in the Upper Silurian rocks, could have been regarded only as of later date to Group D, and not contemporaneous with it. He refers also to the great length of time during which the contemporaneity of these two

* See also Bulletin Soc. Géol. France, deux. sér. tome viii. p. 152 *et seq.* Janv. 1851.

† See Ideal Section, *loc. cit.* pl. 3.

faunas must have lasted,—a period measured by a deposit 1200 metres thick, that forms the upper strata of Group D.

[More or less analogous phænomena are pointed out by M. C. Prevost (Bullet. *l. c.* p. 156), Prof. Bronn (Jahrb. *l. c.* p. 307), and M. Barrande himself (Bullet. *l. c.* p. 158), amongst which are references to the Inferior and Great Oolites—see Morris and Lycett's Monograph on the Great Oolite Mollusca, Pal. Soc., 1850; Lycett, on the Minchinhampton Oolite, Ann. Nat. Hist. 1848, vol. ii. p. 248 *et seq.* (noticed, Jahrb. 1850, p. 869), and Brodie on the Lower Oolite near Cheltenham, Quart. Journ. Geol. Soc. 1850, vol. vi. p. 239 *et seq.* (see Remarks, Jahrb. 1851, p. 487); and to the Oolite and Cretaceous Rocks of Portugal, see Sharpe, Quart. Journ. Geol. Soc. 1850, vol. vi. p. 101 *et seq.* (noticed, Jahrb. 1850, p. 638).]

[T. R. J.]

On the FORAMINIFERA *of the neighbourhood of* BASLE.

By P. MERIAN.

[Bericht Verhandl. Naturf. Gesellsch. Basel, 1851, ix. pp. 49, 50.]

VERY few Foraminifera have been as yet noticed from the Jurassic deposits, their minuteness occasioning them to be overlooked. In the lower division of the "Sequanian" formation there is a bed completely filled with small fossils. In an excursion made in the neighbourhood of Pruntrut by the author, accompanied by M. Jos. Köchlin and M. Thurmann, the latter discovered a fine *Cristellaria*, which was shortly after found in great abundance in a corresponding bed by the author and M. Köchlin. To this species, which is undescribed, M. Merian gives the name *Cristellaria Sequana*. The hornstone-concretions in the Coralline limestone of Istein are particularly rich in Foraminifera, which is also the case with the hornstone and jasper-concretions of Hertingen, Liehl, Auggen, &c. in Baden; and the same species appear to be found in the siliceous nodules of the Coralline limestone as in those of the pea-iron-ore. The matrix appears to have been very favourable for the preservation of these small animal remains; for scarcely a nodule can be found in either of these formations that does not contain Foraminifera. M. Merian found a *Nodosaria* in great abundance in all the localities named; a *Cristellaria* in the hornstone of the pisolite deposit of Hertingen; and a third species, with an irregular spiral shell, whose form cannot be entirely made out from the specimens, in the yellow jasper of Auggen. Farther research in these siliceous formations will doubtless produce more species. M. Merian has never yet found anything of the kind in the numerous hornstone-nodules of the Muschelkalk.

In the compact calcareous Molasse of Stettin near Basle, which is of tertiary age, M. Merian has also found two species of Foraminifera, a *Quinqueloculina* and a *Spiroloculina*, and expects on further search to find more. No fossils of this class have yet been quoted by name from the extensive Molasse series of the centre of Switzerland. Its matrix is usually not favourable for preserving these small animals in a recognizable condition.

[J. C. M.]

On Tertiary Deposits *in the* Würtemberg Alps.

By O. Fraas.

[Würtemb. Jahreshefte, 1851, vol. viii. p. 56–59; and Leonhard u. Bronn's N. Jahrb. f. Min. u. s. w. 1852, 3 H. p. 345.]

The tertiary pisolite beds [Bohnerz, Fer oolitique, Pea-iron-ore] are of two ages. Generally they occupy channels, basins, clefts, and holes in the massive limestone and spongites-beds (Quenstedt's "plumpen Felsenkalken und Spongites-Bänken," ε. and γ. of the White Jura *), the walls of the cavities being quite covered with radiating calc-spar. These generally contain teeth of *Mastodon*, *Hippotherium*, *Equus*, *Elephas*, and Rodents, mostly broken and rolled. Similar deposits are found at Salmendingen, Melchingen, and Onstmettingen, where human teeth also and works of art have been found.

The caverns with *Palæotherium* are of another kind. In going from Mess-stetten through the Hardt, on the Baden frontier, on the way to Stetten and opposite the smelting-house at Thiergarten, close on the frontier we come to a valley, which is deep and wide, but has no outlet. It is about half a square mile in extent. This is the Härdtle of Fronstetten, evidently an old sea-basin, wherein the waters of the neighbouring wooded heights of "White Jura" rocks have collected and still collect, to pass away by subterranean channels, leaving behind the collected bones and gravel. In this basin-like valley, the pisolite-pits, close on the old rocky shore, give the following section:—

	feet.
1. Mould	2
2. Very fine pisolite, with a few well-preserved teeth of *Palæotherium*	8
3. Yellow clay and gravel of the jurassic rocks, without pisolite and teeth	12
4. Clay-bed, rich in pisolite, bones, and teeth	1½ to 2
5. Very pure pisolite, much coarser than No. 2, without teeth	15
	39

Among the remains here discovered, all Cuvier's species of *Palæotherium* and *Anoplotherium* † are recognizable, especially the smaller forms. The enamel of the teeth is in beautiful condition, and the cavities of the bones are filled with the pisolite. Of the bones and teeth—

0·90 belong to *Palæotherium*: those of the more common species are in equal proportion.

0·08 belong to *Anoplotherium*: those of *A. leporinum* are beautifully preserved.

00·1 belong to *Palæomeryx*.

00·1 belong to Reptiles of the White Jura: these are accompanied with remains of *Terebratulæ*, *Cidarites*, and *Apiocrini*, from the same rocks.

0·02 belong to Carnivora.

* See Quart. Journ. Geol. Soc. vol. viii. Part 2, Miscell. p. 69.

† See also Bulletin Soc. Géol. France, deux. sér. tome ix. p. 266, Mars 1852.

Half a mile distant from this pit is the Winterling sand-pit, containing *Cerithium*, *Voluta*, *Venus*, and numerous teeth of *Otodus* and *Lamna*, which, as genera, have reference to the *Calcaire grossier*. The clays, then, of Fronstetten and Neuhausen would correspond to the gypsum, and the limestone of Winterling, Bachzimmern, and Blumberg, to the *Calcaire grossier* of the Paris basin. [T. R. J.]

On the TERTIARY CLAYS *at* OSNABRÜCK. By E. BEYRICH.

[Geolog. Zeitschrift, 1851, vol. iii. p. 211–213; and Leonhard u. Bronn's N. Jahrb. f. Min. u. s. w. 1852, 3 H. p. 358.]

AMONG the shells collected by Fred. Roemer in these clays, there are only a few eocene species, and indeed only such as elsewhere reach to the pliocene series, as *Typhis horridus* and *Dentalium entale*. On the other hand, of characteristic miocene and pliocene species are found—

Conus antediluvianus, *Brocc.*
Pyrula reticulata, *Lam.*
Fusus politus, *Ren.*
Natica Guillemini, *Peyr.*
Turritella subangulata, *Brocc.*
Cytherea multilamella, *Lam.*
Isocardia cor, *Lam.*
Limopsis aurita, *Br.*
—— minuta, *Phil.*

These clays best correspond, not to the septarian clays of Brandenburg, but to the longer known tertiary marls which are equivalent to those of the Doberg near Bünde and the beds of Freden, Dieckholz, and Kassel. There are also among the shells from Bersenbrück three species, which Goldfuss described from Griffel near Winterswyck in Geldern, viz. *Astarte concentrica*, *Cardita chamæformis*, and *Isocardia cor*.

Compared with Dumont's classification for Belgium published in 1849, the whole of the Tertiary formations of North Germany would be equivalent only to the three groups by him termed miocene, —*Systèmes Tongrien, Rupelien et Bolderien*, the second of which comprises the clays of Boom and Baesele, which are identical with the septarian clay of Brandenburg. To this system in North Germany may perhaps belong, as a younger member, the beds from which the Sternberg stone is obtained. To the *Système Tongrien* the green sandy and argillaceous sandy beds would belong, which, about Magdeburg, cover partly the Brown-coal and partly the older rocks; to the *Système Bolderien*, the typical miocene strata of Osnabrück, Bünde, Hildesheim, and Cassel, probably also of Holstein, Lüneburg, and Sylt Island. M. Beyrich does not determine whether the two older Belgian systems should be more correctly termed Upper Eocene, or Lower Miocene. From the stratigraphical conditions in North Germany the author assents to Dumont's view, drawn from similar Belgian conditions, in opposition to D'Archiac, that the clays of the *Système Rupelien* are not the equivalent of the London clay, but overlie the *Système Tongrien*, which covers, near Brussels, the equivalent of the *Calcaire grossier* of Paris. Still less do the septarian clays of Brandenburg belong to the *Calcaire grossier*. [T. R. J.]

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TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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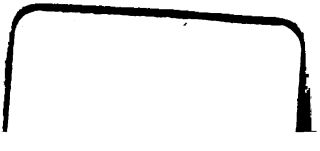
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